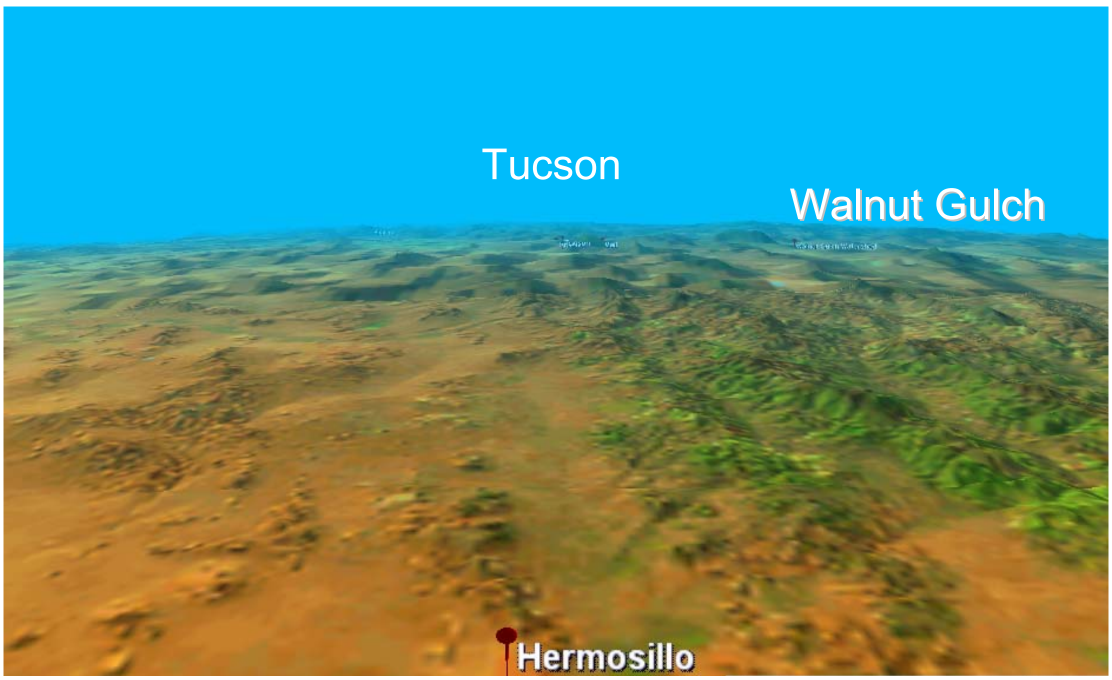
SOIL MOISTURE EXPERIMENTS IN 2004 (SMEX04)

and the

North American Monsoon Experiment (NAME)



Experiment Plan
June 2004

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0 EXECUTIVE SUMMARY

Field experiments in support of remote sensing, hydrology and climate have included catchments throughout North America (Little Washita, Oklahoma: SGP97, SGP99, SMEX03; Little River, Georgia: 2000, SMEX03; Walnut River, Iowa: SMEX02). These experiments have been intensive efforts ranging from one to six weeks in duration. The basic approach used in these experiments has been to collect ground-based samples of soil moisture in conjunction with aircraft flights at the same time as satellite overpasses. The aircraft instruments operate in low frequency microwave wavebands that are well suited for the measurement of soil moisture. The aims of these experiments have been: validation of remotely sensed data from aircraft and/or space-borne microwave sensors, the mapping of spatial and temporal variability of soil moisture, the relationship of soil moisture to vegetation and the near-surface atmospheric characteristics, and the collection of in-situ gravimetric data for soil moisture for validation of the land surface hydrological models used to simulate the watershed at pre-specified spatial and temporal resolutions.

SMEX04 builds on the preceding experiments by focusing specifically on topography, vegetation and strengthening the soil moisture components of the North American Monsoon Experiment (NAME). One of the main objectives of NAME is to improve prediction of warm season precipitation. Warm season precipitation is highly dependent on convection, which, in turn, is controlled, at least in part, by soil moisture and surface temperature. Therefore, an accurate characterization of spatial and temporal variability of soil moisture is critical to NAME in three ways; the spatial and temporal patterns of soil moisture estimated from remote sensing can be used for initialization and/or updating of the boundary conditions for the land surface component of land-atmosphere models, the spatial and temporal patterns of soil moisture can be used for validation of land surface model outputs, and to discern the relationship between soil moisture and warm season precipitation and associated feedback mechanisms.

The timing of SMEX04 and the NAME EOP are driven by the NAMS. Rainfall statistics demonstrate quite clearly that the field experiment should be centered around the period roughly mid-July to mid-August, when the number of rainy days is large and the possibility of having a having flights prior-to and subsequent to heavy rainfall is high.

SMEX04 will involve four complementary elements; in-situ soil moisture networks, aircraft mapping of soil moisture, intensive sampling concurrent with aircraft mission, and satellite products. Two regional study sites (~50 km by 75 km) have been established in Arizona (AZ) and Sonora (SO). A NASA P-3 aircraft will be the platform for two passive microwave instruments, the Polarimetric Scanning Radiometer (PSR) with X and C band channels and the Two Dimensional Synthetic Aperture Radiometer (2DSTAR) with L band channels. In addition, satellite data from the Aqua AMSR-E, Coriolis Windsat, TRMM TMI, DMSP SSM/I, Terra MODIS and ASTER, and Envisat ASAR will be utilized for soil moisture and vegetation studies at local and regional scales.

1 OVERVIEW AND SCIENTIFIC OBJECTIVES

1.1 Introduction

In much of the interior of the North American continent, summer precipitation is a dominant feature of the annual cycle. Surface boundary conditions play an important role in initiation and maintenance of the North American Monsoon System (NAMS), which controls summer precipitation over much of this region. The most important surface boundary conditions are sea surface temperature and land surface wetness and temperature. The NAMS has important practical as well as scientific implications. Figure 1 shows annual streamflow into the Rio Bravo (known as the Rio Grande in the U.S.) reservoir system since the early 1950s. A prolonged drought over the last 10 years, including two of the lowest yearly discharges in the gauge record, is attributable to reduced summer monsoon rainfall over northern Mexico. The associated drastic reductions in agricultural water supply allocations have resulted in abandonment of agricultural lands in Mexico, international tensions resulting from inability of Mexico to meet treaty obligations relating to inflows to international reservoirs, and additional pressure on Mexican immigration to the U.S.

Two of the four general science questions of the North American Monsoon Experiment (NAME) (http://www.cpc.ncep.noaa.gov/products/precip/monsoon/) relate directly to land surface boundary conditions, specifically:

(1) How is the evolution of the warm season (May-October) atmospheric circulation and precipitation regimes over North America related to the seasonal evolution of oceanic and continental boundary conditions?

(3) What are the significant features of and interrelationships between the anomaly-sustaining atmospheric circulation and the boundary conditions that characterize large-scale long-lasting continental precipitation (and temperature) anomaly regimes?

A working hypothesis of NAME is that among the land surface antecedent boundary conditions that control the onset and intensity of the NAMS are soil moisture and snow extent in the southwestern U.S. and northern Mexico and those in the northwestern U.S. (these usually being out of phase), while the concurrent conditions that typify NAMS are out of phase surface wetness and temperature in the southwestern U.S. and northern Mexico, on the one hand, and in the U.S. Great Plains, on the other. The influence of the land surface is relayed through surface evaporation and associated surface cooling (dependent on soil moisture), terrain, and vegetation cover. Soil moisture and, in particular, surface wetness, can change dramatically after heavy rain events. Increased soil moisture after precipitation promotes evapotranspiration between storm events. This may contribute to enhanced convection and further precipitation. Soil moisture can vary both spatially, due to topography, soil, vegetation and precipitation variability, and temporally, due to differences in soil physical characteristics that control drainage and accumulated evapotranspiration.

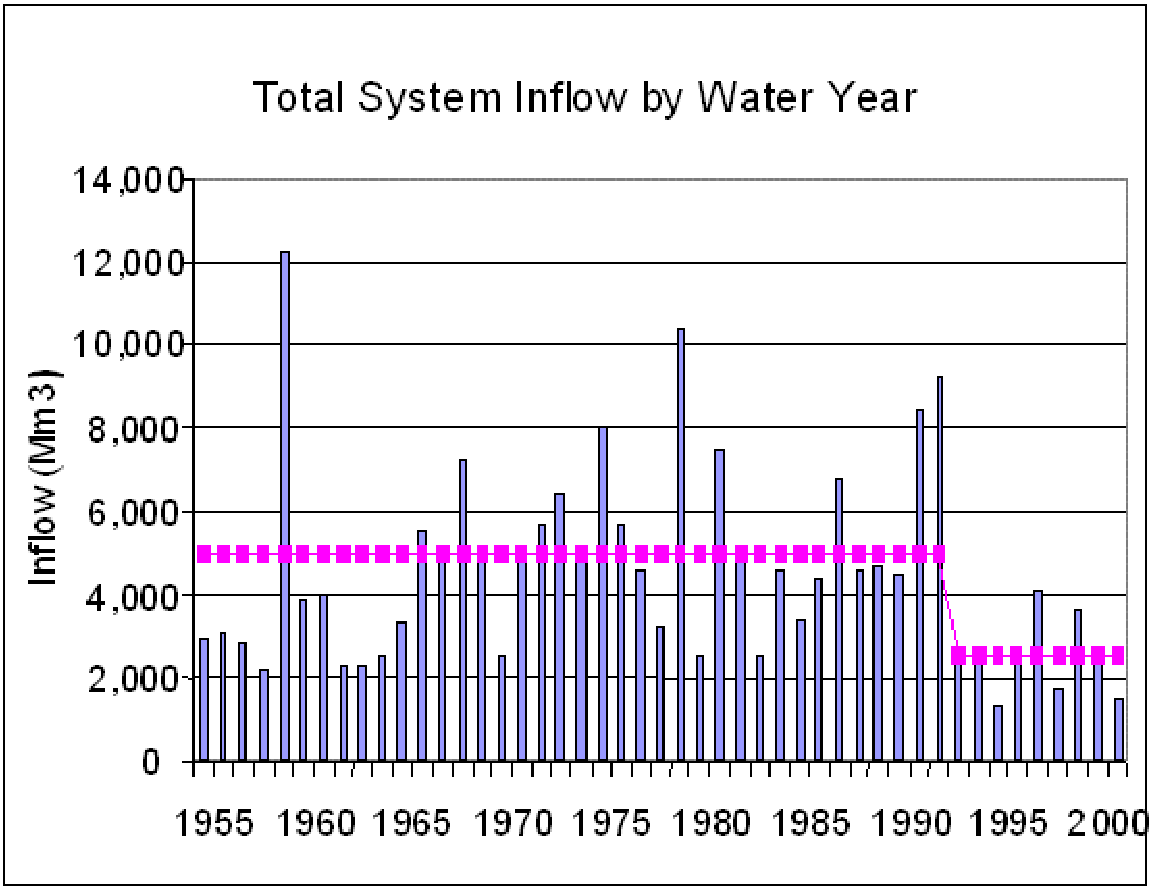


Figure 1: Total annual inflow to the Rio Bravo reservoir system, 1954-2001. [Note that three years during the drought period starting in 1993 have lower flows than any previously observed in the 48-year record. Figure from Vigerstol (2002).

Over much of the NAME region soil moisture observations are sparse and even precipitation observations that might be used to derive estimates of surface wetness are inadequate, especially in the region of northern Mexico that seems to be critical in initiating NAMS convective activity (Carbone 2002). The Soil Moisture Experiment 2004 (SMEX04) described here will focus on providing these critical soil moisture products using the new generation of satellite sensors. It will at the same time contribute to the validation of these products and expand our knowledge of the effects of key land surface features and the potential of new technologies for soil moisture mapping.

Remote sensing provides an alternative means of observing spatial and temporal variations in surface wetness over the region. Frequent derived estimates of soil moisture over much of the NAME region should be made possible through recently launched satellite microwave sensors, including the Advanced Microwave Scanning Radiometer (AMSR-E) on Aqua as well as the TRMM Microwave Imager (TMI). Figure 2 shows a sequence of TMI brightness temperature images for a few days in July of 2002 over the general NAME Tier 1 region (Figure 3). There is spatial structure and temporal consistency of some features. We also can observe a very large range of brightness temperatures, which suggests a high probability of success in deriving soil moisture.

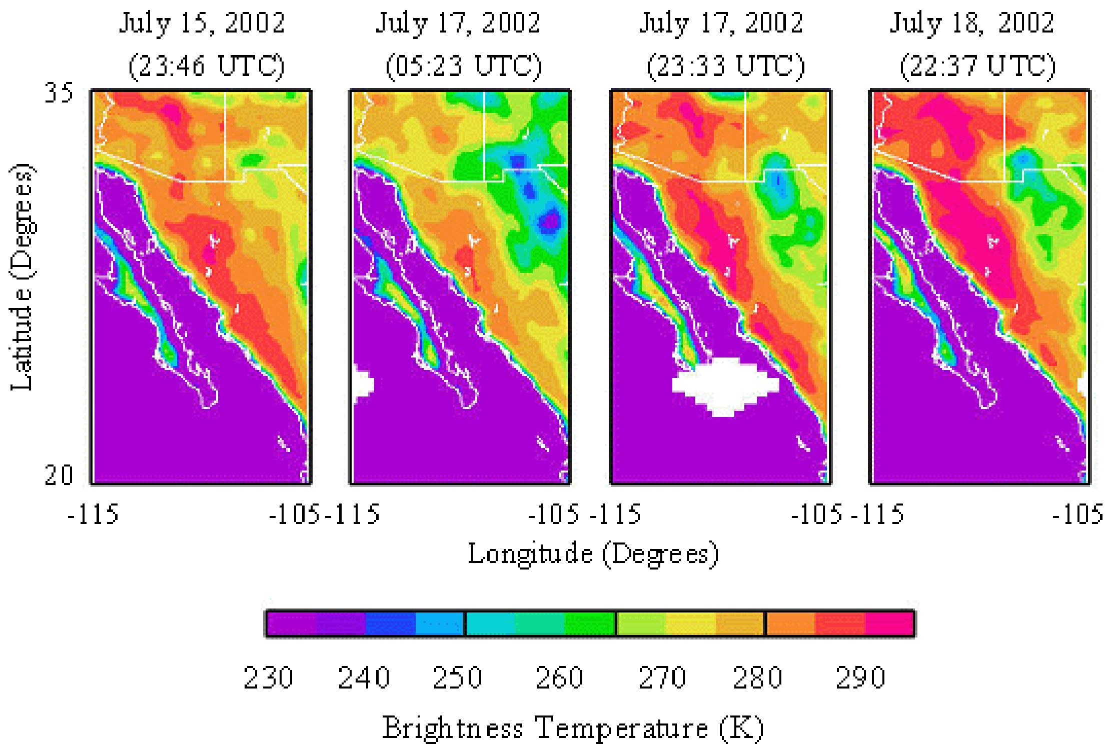


Figure 2. TRMM Microwave Imager 10.7 GHz H polarization maps of brightness temperature for the NAME Tier 1 region.

SMEX04 provides an excellent opportunity to evaluate AMSR products because much of the region has relatively sparse vegetation, which is important given the relatively short sensor wavelength (for soil moisture applications). Herein we propose to use high spatial resolution aircraft-borne passive microwave instruments with frequencies similar to AMSR and future L-band soil moisture missions (*SMOS* Kerr et al. 2001 and *Hydros* Entekhabi et al. 2004), along with strategically located and designed automated and manual surface observations, to verify and extend the satellite observations over portions of the NAME region with sparse vegetation (here roughly delimited as areas with 3 kg/m^2 total vegetation biomass).

As outlined at http://www.cpc.ncep.noaa.gov/products/precip/monsoon/ in the NAME Science and Implementation Plan, hydrology and soil moisture are fundamental components of NAME research. At present, however, there are no provisions for collecting soil moisture observations. The U.S. CLIVAR Panel, in its review of the NAME Science and Implementation Plan, specifically pointed out that the land activities within NAME should be enhanced. Moreover, a soil moisture field component of NAME will provide an opportunity for the NASA Terrestrial Hydrology, Global Water Cycle, and Aqua AMSR-E Programs to become involved in a problem that has important scientific and practical implications while simultaneously addressing key NASA science priorities.

1.2 North American Monsoon Experiment (NAME)

The physical domain of the NAME comprises three tiers (see Figure 3). Field activities, high-resolution modeling, and the focus of most observation activities will be on Tier 1. However, it is recognized that the implications to and of the NAMS extend beyond the Tier 1 core region and, for this reason, larger Tier 2 and 3 domains are defined within which supporting modeling and other activities will be conducted, as necessary. It is worth noting that most of Tier 1 lies within the domain of the Land Data Assimilation System (LDAS) (Mitchell et al. in review) (which extends south to 25 N), and LDAS will therefore be able to provide some key information, such as historic precipitation and derived (modeled) soil moisture that will be important for comparison with satellite and aircraft observations.

The scientific objectives of NAME outlined in the Science and Implementation Plan (*http://www.cpc.ncep.noaa.gov/products/precip/monsoon/*) are to promote a better understanding and more realistic simulation of:

(1) Warm season convective processes in complex terrain (Tier 1);
(2) Intraseasonal variability of the monsoon (Tier 2);
(3) The response of the warm season atmospheric circulation and precipitation patterns to slowly varying, potentially predictable oceanic and continental surface boundary conditions (Tier 3);
(4) The evolution of the North American monsoon system and its variability.

In addition to these scientific objectives, NAME researchers will:
(5) interact with applications, assessment, and human dimensions researchers on the potential use of NAME science by end users.

The NAME Science and Implementation Plan specifically targets:

(1) Empirical and modeling studies, data set development, and enhanced monitoring activities that carry on some elements of the existing PACS program and the US CLIVAR/GEWEX Warm Season Precipitation Initiative (2000 onward) while initiating new elements to provide the spatial and temporal context for the NAME;
(2) *Field activities in the core region of the North American monsoon during the summers of 2004, including build-up, field, analysis and modeling phases (2003-2008);*
(3) Strong links between the VAMOS element of CLIVAR, US CLIVAR Pan American research, and the GEWEX America Prediction Project (GAPP).

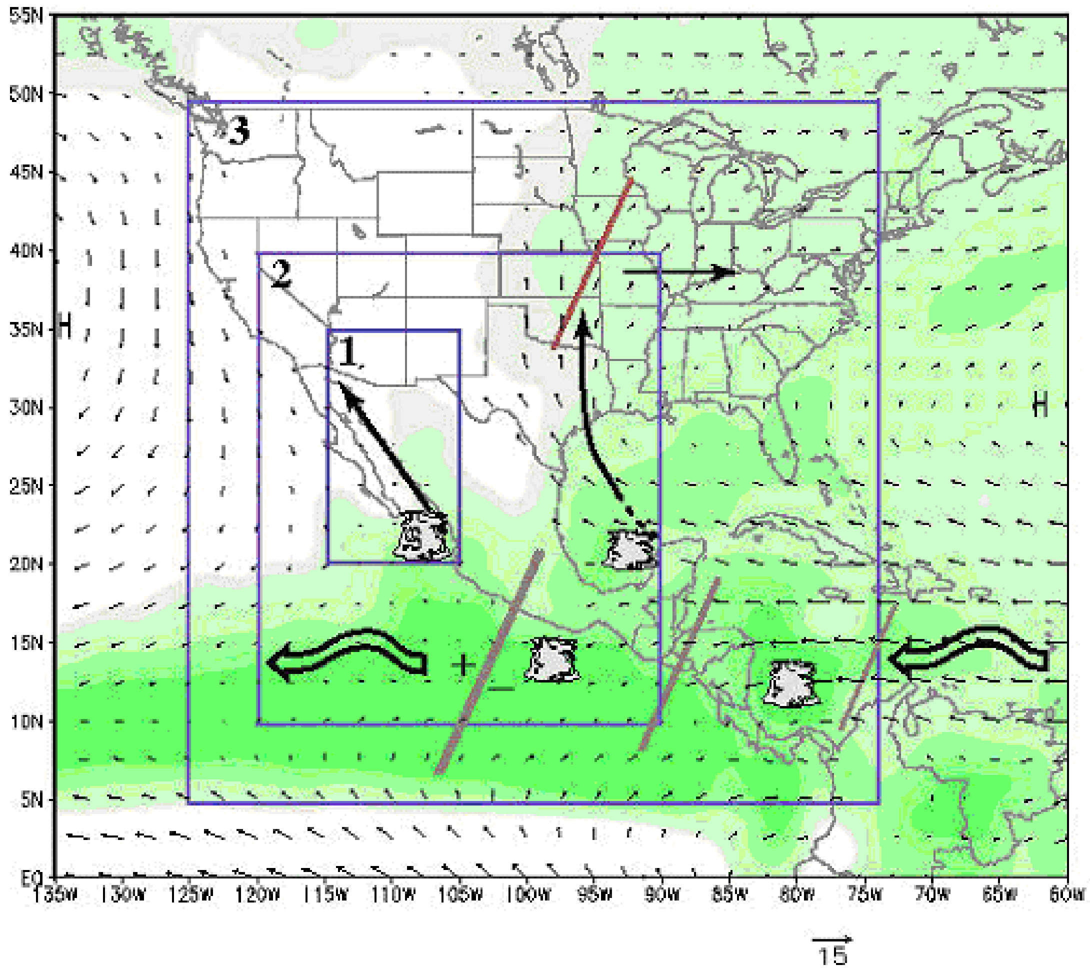


Figure 3. Scheme illustrating the multi-tiered approach of the North American Monsoon Experiment (from the NAME Implementation Plan).

The italic items above indicate the specific land activities of the NAME to which SMEX04 would address. The broader 2004 intensive observing period and associated field campaign is central to the NAME. It will consist primarily of oceanographic and near-surface atmospheric, and aircraft micrometeorological and cloud physics data collected from flight lines of the NOAA P3. Land surface observations would be limited mainly to supplemental rain gauge transects along several major mainland roads from the coast inland to the Sierra Madre crest. A limited number of surface flux towers will be operated as part of NAME, however, these will be further south than the soil moisture study regions.

Although the supplemental precipitation gage network is expected to provide much higher quality data than are currently available, especially in areas of complex terrain, and will help to understand the interaction of topography and the diurnal cycle of precipitation during the monsoon period, it is not logistically feasible to provide a spatial context for variations in soil moisture from the transects alone. For this reason, we are conducting a soil moisture field activity that, in combination with LDAS and related supplemental products from the enhanced rain gauge network, will allow estimation of surface wetness over the NAME Tier 1 domain.

1.3 Relevance to NASA Hydrology Programs

The current research priorities of the NASA Terrestrial Hydrology Program (THP) related to soil moisture include science objectives that are complementary to the NAME project. These are:

(1) The development and validation of soil moisture retrieval algorithms using microwave remote sensing in regions with moderate to significant topographic variation;
(2) Validation of soil moisture products from the Aqua AMSR-E (Advanced Microwave Scanning Radiometer) instrument;
(3) Establishing long-term in situ soil moisture validation sites for satellite based retrievals;
(4) Evaluation of new sensor technologies and algorithms for future soil moisture missions including Hydros and SMOS;
(5) Understanding the feedback mechanisms of surface soil moisture on weather and climate;
(6) Development of methods to assimilate surface soil moisture observations in models.

The NAME region includes a wide range of arid to semi-arid conditions and heterogeneous topography that would allow us to address objective 1. Between Hermosillo Mexico and Tombstone Arizona (Figure 4) the topography varies from flat deserts to mountains with elevations of more than 2500 m.

As part of ongoing efforts to validate soil moisture products from AMSR-E, several watershed sites in the U.S. have been instrumented to provide continuous long-term observations of surface soil moisture and temperature. The Aqua calibration/validation plan includes intensive experiments to calibrate and validate these sites using ground and aircraft observations. One of the sites is the Walnut Gulch Watershed near Tombstone Arizona. This site is in the NAME Tier 1 region and is hydrologically dominated by the NAMS. Integrating Walnut Gulch into the SMEX04 and NAME soil moisture field activities provides a bridge to the Aqua AMSR-E program and to the soil moisture remote sensing and summer Monsoon rainfall studies conducted there in the past. A second target site, which will also include insitu observations, has been established in the Sonora region of Mexico. The Sonora area is linked to the northern (Walnut Gulch) site by a major highway and has surface characteristics (topography, soils, and vegetation) that would complement but not duplicate those of the Walnut Gulch site with increased vegetation and topographic variability. The soil moisture activity would address objectives 2 and 3 of the NASA Terrestrial Hydrology Program.

The instruments providing soil moisture information to be flown on aircraft during the SMEX04 would include the L-Band passive microwave Two Dimensional Synthetic Aperture Radiometer (2DSTAR) and the NOAA Polarimetric Scanning Radiometer (PSR) with C and X band. If feasible, a Global Positioning System (GPS) based reflectometer used in previous experiments will also be included. Of these, the 2DSTAR and GPS represent new technology that is currently under development, and would therefore address THP's objective 4.

THP's objectives 5 and 6 are central to the NAME science questions and objectives laid out in the Science and Implementation Plan. Consequently, the proposed soil moisture activity of

SMEX04 in particular, and NAME, in general, is highly complementary with the Terrestrial Hydrology Program's soil moisture priorities.

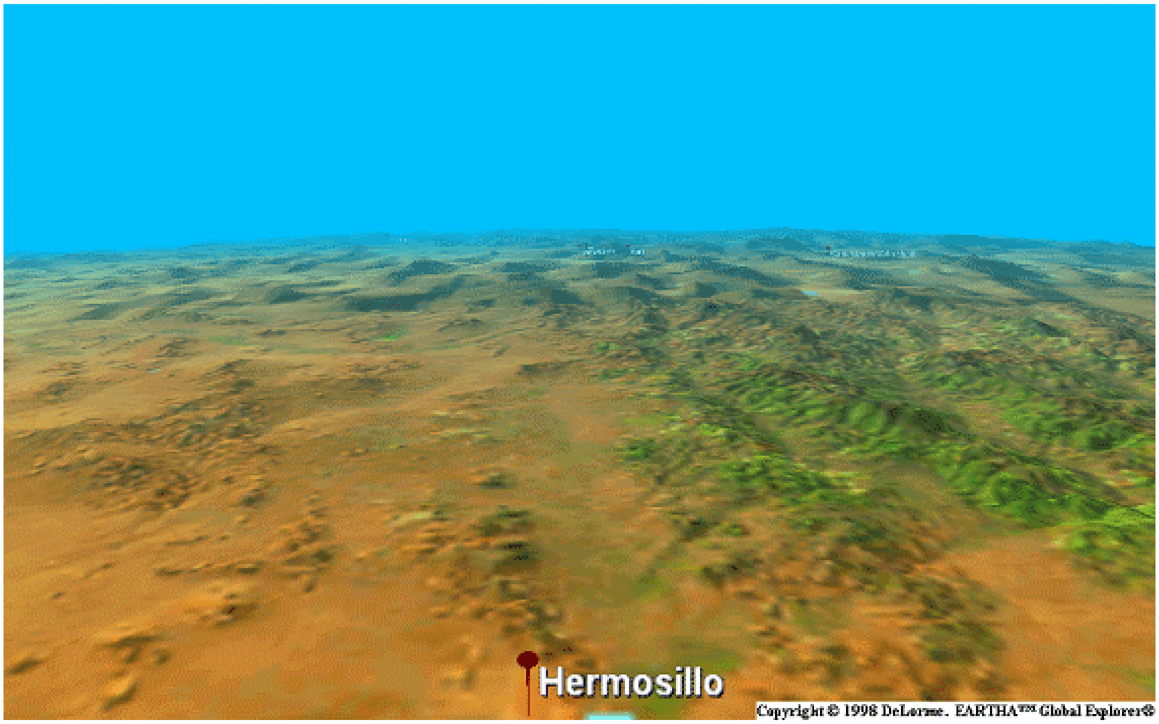


Figure 4. Three-dimensional perspective of the SMEX04 and NAME region looking north from Hermosillo to Tucson.

1.4 Elements of Soil Moisture Experiments in 2004 (SMEX04)

Field experiments in support of remote sensing, hydrology and climate have included catchments throughout North America (Little Washita, Oklahoma: SGP97, SGP99, SMEX03; Little River, Georgia: 2000, SMEX03; Walnut River, Iowa: SMEX02). These experiments have been intensive efforts ranging from one to six weeks in duration. The basic approach used in these experiments has been to collect ground-based samples of soil moisture in conjunction with aircraft flights at the same time as satellite overpasses. The aircraft instruments operate in low frequency microwave wavebands that are well suited for the measurement of soil moisture. The aims of these experiments have been:

(1) Validation of remotely sensed data from aircraft and/or space-borne microwave sensors, including validation of the retrieval algorithm and/or calibration of certain non-physical parameters in these algorithms
(2) The mapping of spatial and temporal variability of soil moisture, specifically, the spatial and temporal patterns after a dry-down.
(3) The relationship of soil moisture to vegetation and the near-surface atmospheric characteristics, as well as land-atmosphere interaction variables such as evapotranspiration and latent heat fluxes.

(4) The collection of in-situ gravimetric data for soil moisture for validation of the land surface hydrological models used to simulate the watershed at pre-specified spatial and temporal resolutions.

One of the main objectives of NAME is to improve prediction of warm season precipitation. Warm season precipitation is highly dependent on convection, which, in turn, is controlled, at least in part, by soil moisture and surface temperature. Therefore, an accurate characterization of spatial and temporal variability of soil moisture is critical to NAME in three ways, viz.,

(1) The spatial and temporal patterns of soil moisture estimated from remote sensing (by aircraft so as to provide high spatial resolutions) can be used for initialization and/or updating of the boundary conditions for the land surface component of land-atmosphere models.
(2) The spatial and temporal patterns of soil moisture can be used for validation of land surface model outputs, and to discern the relationship between soil moisture and warm season precipitation and associated feedback mechanisms.
(3) Aircraft-based soil moisture mapping can provide a basis for model-based extrapolation over Tier 1, using methods developed under LDAS and AMSR validation studies. For the larger Tier 2 and 3 regions, satellite retrievals using AMSR will be most appropriate, and will be validated using AMSR data as well as in-situ measurements from networks like the Oklahoma Mesonet.

The timing of SMEX04 and the NAME Enhance Observing Period (EOP) are driven by the NAMS. Table 1 shows the number of rainy days in the NAME area for the Hermosillo Mexico region for 1965-2001. This table also gives the average monthly rainfall in Hermosillo. These statistics illustrate interesting aspects of the regional precipitation. First, the number of rainy days in June is very small, i.e.1-4 days whereas the number of rainy days in July/August is much larger, viz., 6-18 days. Secondly, the average rainfall in June is 7.3 mm whereas the average rainfall in July/August is 90.7/94.7 mm (greater by a factor of 10). About half of the annual precipitation falls in July and August.

These statistics demonstrate quite clearly that the field experiment should be centered around the period roughly mid-July to mid-August, when the number of rainy days is large and the possibility of having a having flights prior to and subsequent to heavy rainfall is high.

SMEX04 will involve four complementary elements;

- In-situ soil moisture networks
- Aircraft mapping of soil moisture
- Intensive sampling concurrent with aircraft mission
- Satellite products

Ground based observations will include a combination of insitu and mobile soil moisture data collection. Networks of continuous point observations of surface soil moisture have been established within the two regions of the study domain. One of these includes the Walnut Gulch Watershed in Arizona. The other is within northern Mexico. Each regional network utilizes the same soil moisture instrumentation (Vitel sensors HYD-50A). Each network has 15 or more sites distributed over a nominal AMSR-E low frequency footprint. Data will be collected continuously over an extended time period, longer than the EOP.

Table 1. Rainfall (1965-2000) Characteristics by Month for Hermosillo Mexico

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Number of days with Rainfall	2.5	2.1	1.3	0.7	0.4	0.9	9.4	8.5	4.5	1.9	1.6	3.1
Maximum Number of days with Rainfall	8	7	5	3	4	5	18	14	11	9	5	9
Average Monthly Rainfall (mm)	18.2	18.6	7.2	3.9	3.7	7.3	90.7	94.7	53.2	17.5	15.1	27.1

The sparse networks described above would be supplemented with more intensive observations by mobile teams during the intensive observing period on specific days with either aircraft and/or satellite observations. The soil moisture sampling teams would use more traditional methods. Data would be collected by teams from the participating U.S and Mexican institutions.

Aircraft observations provide the critical bridge for scaling and integrating the point observations to the coarse satellite footprints. In addition, the higher resolution aircraft soil moisture products are of value in more intensive hydrologic investigations. A NASA aircraft (P-3B) will be used that will have X, C, and L band microwave radiometers. Missions will be flown approximately every other day and timed to coincide with satellite coverage.

By the time of SMEX04, both U.S. and Japanese AMSR-E algorithm science teams will be producing standard soil moisture products for areas of low vegetation cover. The experiment team will facilitate the analysis and distribution of these products to the broader NAME science and forecast team for evaluation. This will be continued beyond the IOP and may be expanded to the entire Tier 1 area or larger domain.

2 REGIONAL SOIL MOISTURE NETWORKS

Two regional study sites will be used, Walnut Gulch Arizona (AZ) and Sonora Mexico (SO). The general vegetation conditions for the two sites are shown in Figure 5. Vegetation in AZ will be less than SO as will be the topographic variability. The following sections describe these sites and the regional networks.

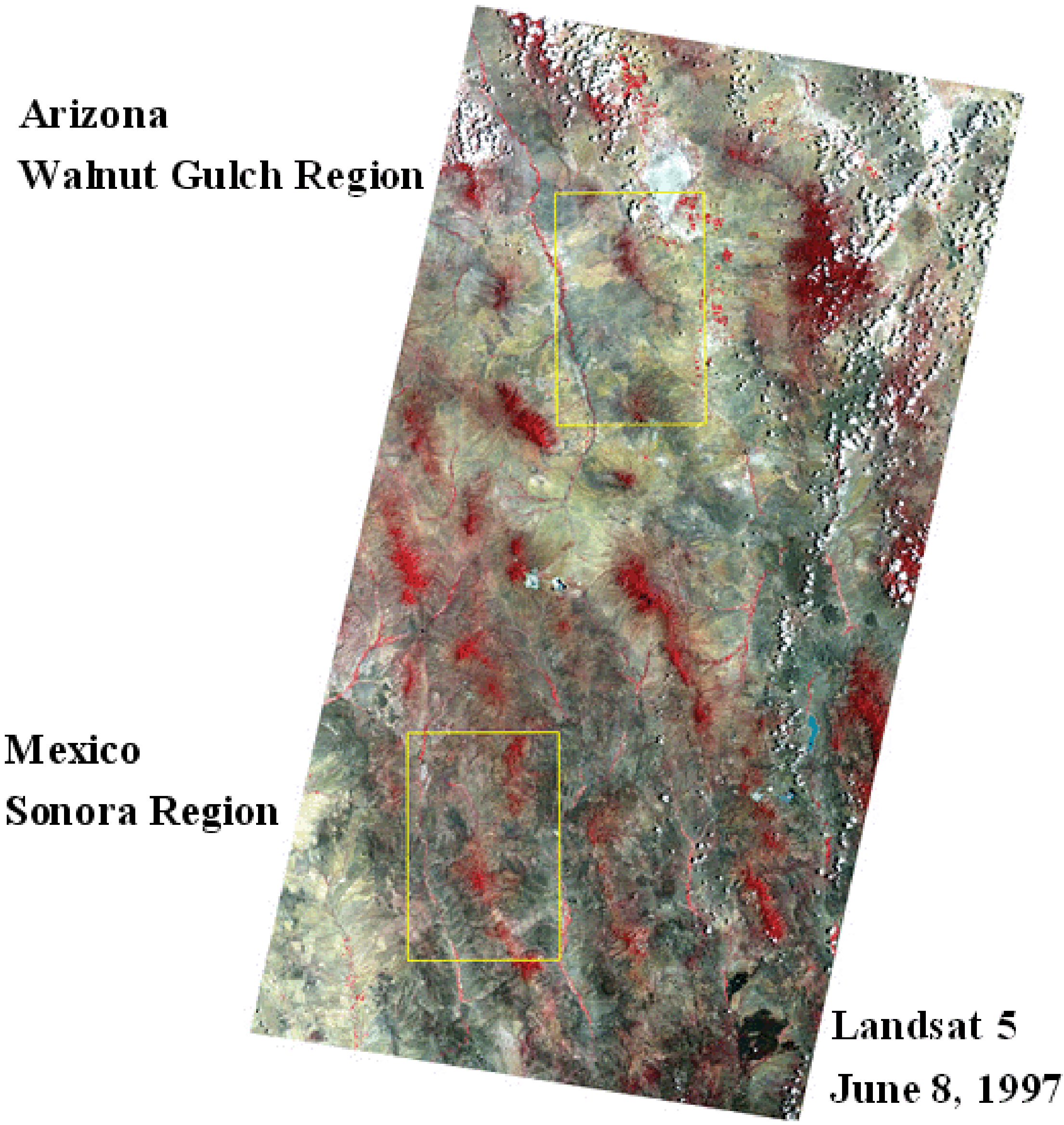


Figure 5. Landsat image with regional study areas.

2.1 Arizona Region

2.1.1 Region Description

The core of the Arizona region (AZ) is the USDA-ARS Walnut Gulch Experimental Watershed (http://tucson.ars.ag.gov/unit/Watersheds/WGEW.htm. The Walnut Gulch Experimental Watershed encompasses the 150 square kilometers in southeastern Arizona, U.S.A. (31^{o} 43'N, 110^{o} 41'W) that surrounds the historical western town of Tombstone. The watershed is contained within the upper San Pedro River Basin, which encompasses 7600 square kilometers in Sonora, Mexico and Arizona (Figure 6). The watershed is representative of approximately 60 million hectares of brush and grass covered rangeland found throughout the semi-arid southwest and is a transition zone between the Chihuahuan and Sonoran Deserts. Elevation of the watershed ranges from 1250 m to 1585 m MSL. Cattle grazing is the primary land use with mining, limited urbanization, and recreation making up the remaining uses. Walnut Gulch, being dry about 99% of the time, is an ephemeral tributary of the San Pedro River.

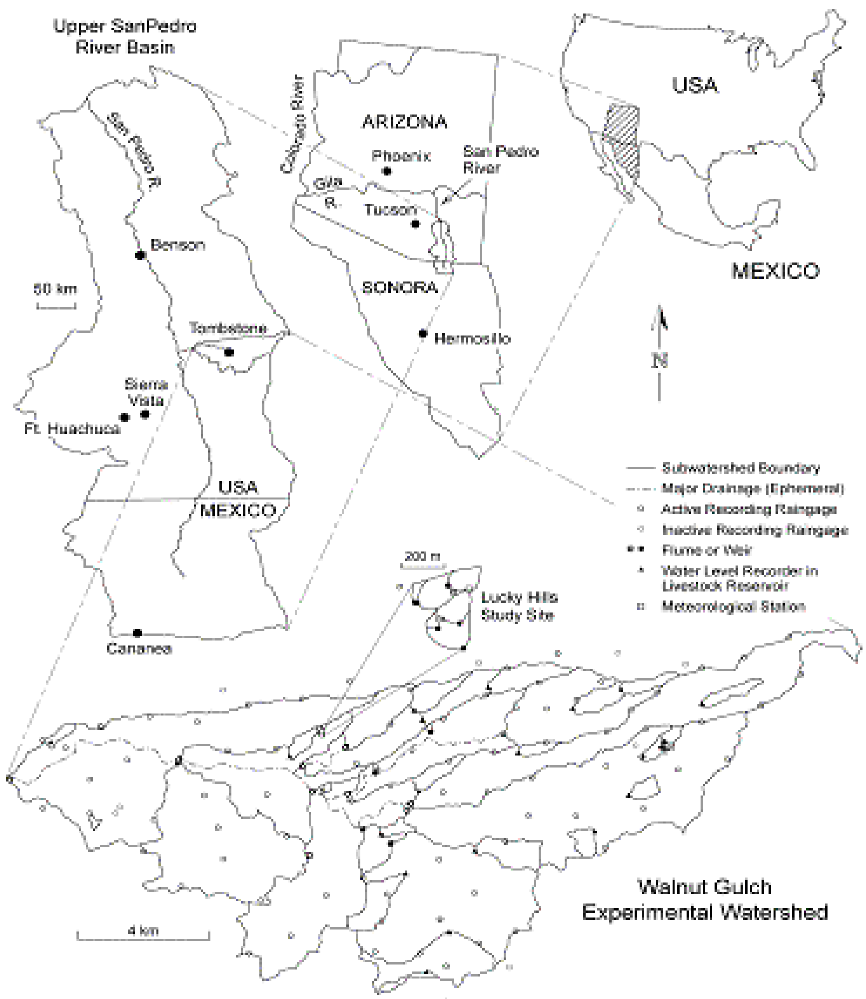


Figure 6. Arizona-Walnut Gulch region.

Walnut Gulch was the focus of the Monsoon'90 experiment (Kustas et al. 1991) that included extensive microwave remote sensing (Jackson et al. 1994, Goodrich et al. 1994, Schmugge et al. 1994) and subsequent modeling efforts (Houser et al. 1998). In 1991 it was the first soil moisture study conducted with the ESTAR (Jackson et al. 1993).

This region has been the focus of a long term project by USDA and NASA called SALSA (http://www.tucson.ars.ag.gov/salsa/archive/archive.html and http://www.tucson.ars.ag.gov/salsa/archive/documents/background/salsa_fact_sheet_apr98.html.

Climate. Walnut Gulch Experimental Watershed lies in the transition zone between the Sonoran and the Chihuahuan Deserts. The climate is classified as semi-arid, with mean annual temperature at Tombstone of 17.7°C and mean annual precipitation of 350 mm. On average there are 53 days of precipitation per year and most accumulation is as rainfall. The precipitation regime is dominated by the North American Monsoon with slightly more than 60% of the annual total coming during July, August and September; about 1/3 coming during the six months October through March (Figure 7). Summer events are localized short-duration, high-intensity convective thunderstorms driven by the intense solar heating of the land surface and moisture inputs from the Gulf of Mexico and Gulf of California. Winter storms are generally slower moving, frontal systems from the Pacific Ocean. These frontal systems generate longer duration and lower intensity precipitation that covers larger areas. The two opposite phases of the ocean-atmosphere phenomenon El Nino-Southern Oscillation (ENSO), referred to as El Nino and La Nina, affect winter precipitation with greater than normal precipitation during El Nino periods and less than normal precipitation during La Nina episodes. Virtually all runoff is generated by summer thunderstorm precipitation and runoff volumes and peak flow rates vary greatly with area and on an annual basis.

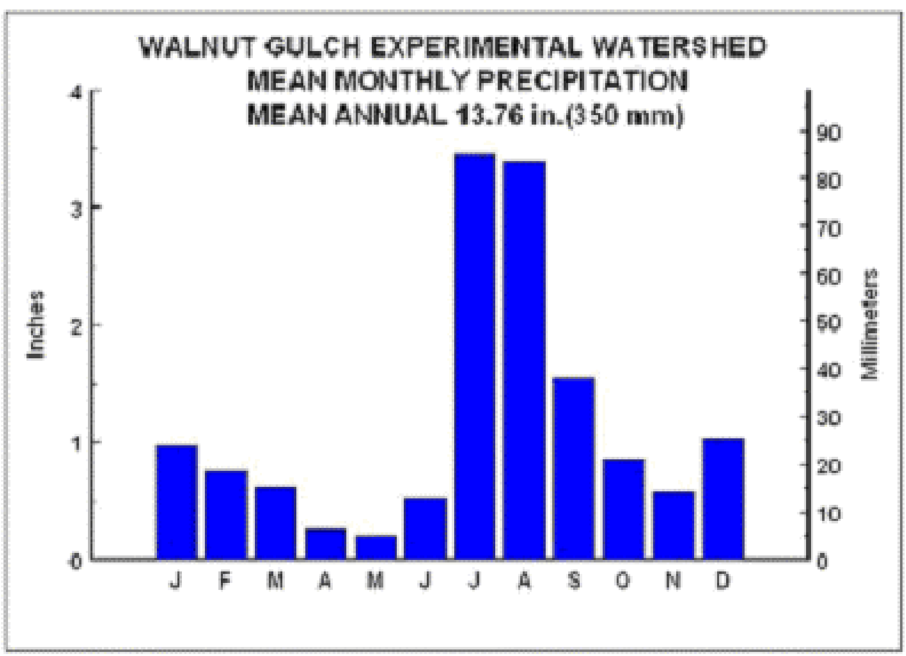


Figure 7. Average monthly precipitation in the Walnut Gulch Watershed.

Soils. Soils on the Walnut Gulch Experimental Watershed reflect the geologic parent material from which they developed (Figure 8). The limestone influenced alluvial fill parent material is dominant on the watershed. The soils that developed from this material are generally well-drained, calcareous, gravelly loams with large percentages of rock and gravel at the soil surface. Soil surface rock fragment cover (erosion pavement) can range from nearly 0% on shallow slopes to over 70% on the very steep slopes. NRCS has mapped 27 soil series on the watershed. The major soil series presently defined on this area are Blacktail (fine, mixed, thermic, Aridic Argistolls), McAllister (fine-loamy, mixed, thermic, Ustollic Haplargids), Elgin (fine, mixed, thermic, Ustollic Paleargids), Sutherland (loamy-skeletal, carbonatic, thermic, shallow Ustollic Paleorthids), Monterosa (loamy-skeletal, mixed, thermic, shallow Ustollic Paleorthids), Stronghold (coarse-loamy, mixed, thermic, Ustollic Calciorthids), Luckyhills(coarse-loamy, mixed, thermic, Ustochreptic Calciorthids). The uppermost 10 cm of the soil profiles contain up to 60% gravel, and the underlying horizons usually contain less than 40% gravel. The remaining soils developed from igneous intrusive materials and are generally cobbly, fine textured, shallow soils.

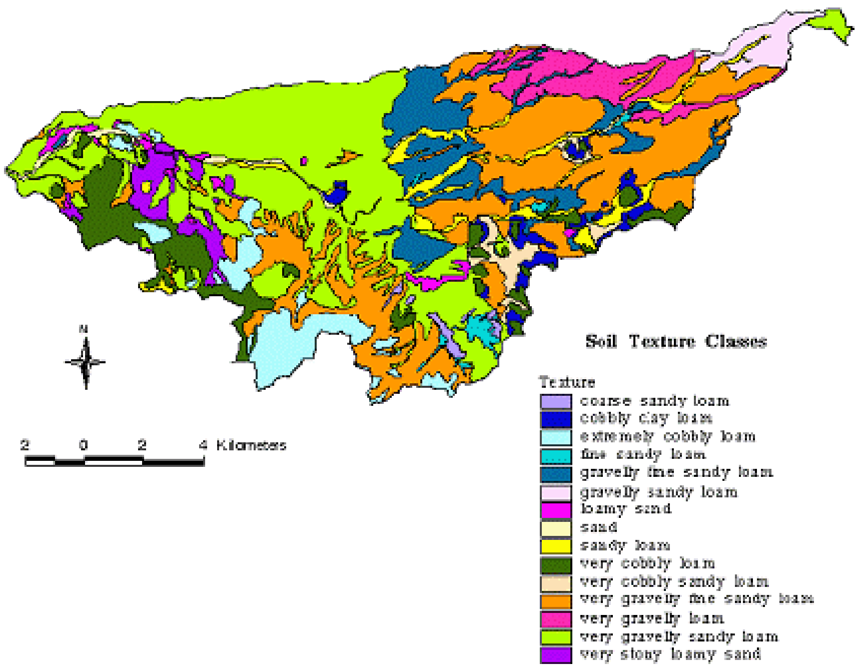


Figure 8. Soil texture map of the Walnut Gulch Watershed**.**

Vegetation. Although historical records indicate that most of the Walnut Gulch Experimental Watershed was grassland approximately 100 years ago, shrubs now dominate the lower two-thirds of the watershed (Figure 9). Major watershed vegetation includes the shrub species of creosote bush (Larrea tridentata), white-thorn (Acacia constricta), tarbush (Flourensia cernua), snakeweed (Gutierrezia sarothrae), and burroweed (Aplopappus tenuisectus); and grass species of black grama (Bouteloua eriopoda), blue grama (B. gracilis), sideoats grama (B. curtipendula), bush muhly (Muhlenbergia porteri), and Lehmann lovegrass (Eragrostis lehmanniana). Shrub canopy cover ranges from 30 to 40% and grass canopy cover ranges from 10 to 80%. Average annual herbaceous forage production is approximately 1200 kg/ha. Figures 10 and 11 illustrate the general features of the vegetation cover in the watershed.

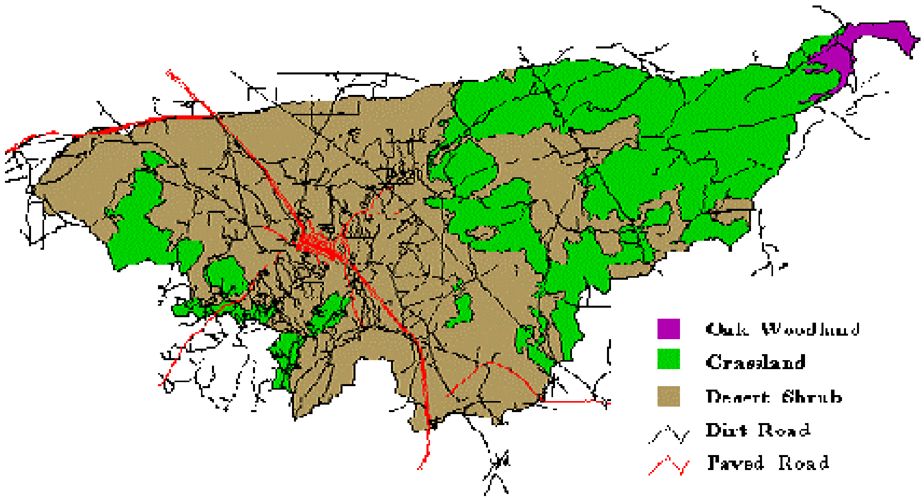


Figure 9. Vegetation map of the Walnut Gulch Watershed.

Figure 10. Shrub dominated lower part of watershed.

Figure 11. Grass dominated upper part of watershed.

Instrumentation. The Walnut Gulch Experimental Watershed is one of the most densely instrumented semi-arid watersheds in the world. Rainfall is currently recorded on a continuous basis at 88 locations using digital recording weighing rain gauges (Figure 12). Runoff is measured using a variety of methods from 29 nested watersheds whose drainage areas range in scale from 0.2 to 14,800 hectares. On a daily basis, all locations are automatically and sequentially queried and data are transmitted to a dedicated computer at the Tombstone field office. Data are archived, used to generate daily reports and written to the Tucson SWRC network server using a 56K phone line.

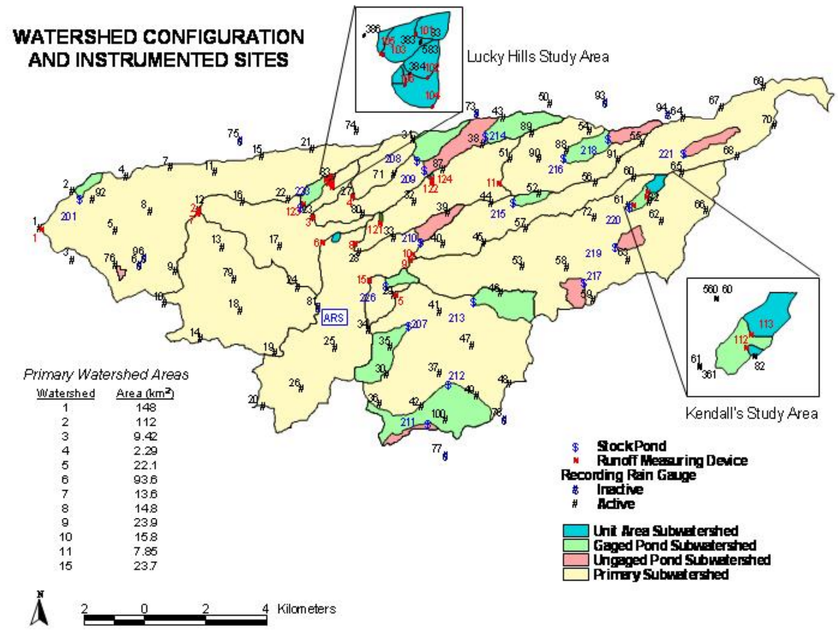


Figure 12. Walnut Gulch raingage sites.

Two intensive study areas of particular interest are the Lucky Hills (brush dominated) and Kendall (grass dominated) unit source watershed areas (nested micro-watersheds ranging in area from 0.2 to 60 ha). At these two sites near continuous energy and water balance measurements have been made since 1990 and since 1996 carbon fluxes have also been measured at these sites. Long term soil moisture and temperature measurements in multiple depth profiles (to roughly 80 cm in depth) have been made since 1990 at the Lucky Hills and Kendall micro-watersheds. Soil moisture has been measured using time domain reflectometry and electrical resistance sensors.

2.1.2 Network Description

The raingage network in the Walnut Gulch Watershed was mentioned above. Recently, as part of a project sponsored by the NASA Aqua Calibration/Validation Program surface soil moisture sensors have been installed at a number of locations in the Walnut Gulch Watershed and surrounding region.

Twenty-seven Vitel soil moisture probes have been installed at twenty-one locations on or near the 150 km^2 the watershed in the vicinity of Tombstone AZ (Figure 13). Nineteen locations are on the watershed, all of which are co-located with electronic-measuring digital-recording raingages; sixteen of these have a single sensor at 5 cm depth, the other three sites on WGEW have a shallow profile array of 3 sensors at 5, 15 and 30 cm. Two sites, both sensors installed at 5 cm, are within about 10 km of WGEW, one north co-located with a recording raingage, one west co-located with a meteorological/flux station. All data are recorded at 30-minute intervals. All three shallow profile sites, all 16 single sensor sites on the watershed and one of the off-watershed single sensor sites have been integrated into the existing radio-telemetry data-acquisition network. Data from this network are automatically downloaded from Campbell Scientific CR10X data loggers daily. The remaining off-watershed sensor is recorded to a Campbell Scientific 21X data logger and manually downloaded every week.

The selected subset of raingage sites (Table 2) provide watershed-area coverage, a range of soil types and accessibility. The sites selected are RG's 3, 13, 14, 18, 20, 28, 34, 37, 40, 46, 57, 69, 70, 76, 82, 83, 89, 92 and 100 (see map and coordinate table). The 19 raingage sites (16 single and 3 profile) are located on 16 different soil types.

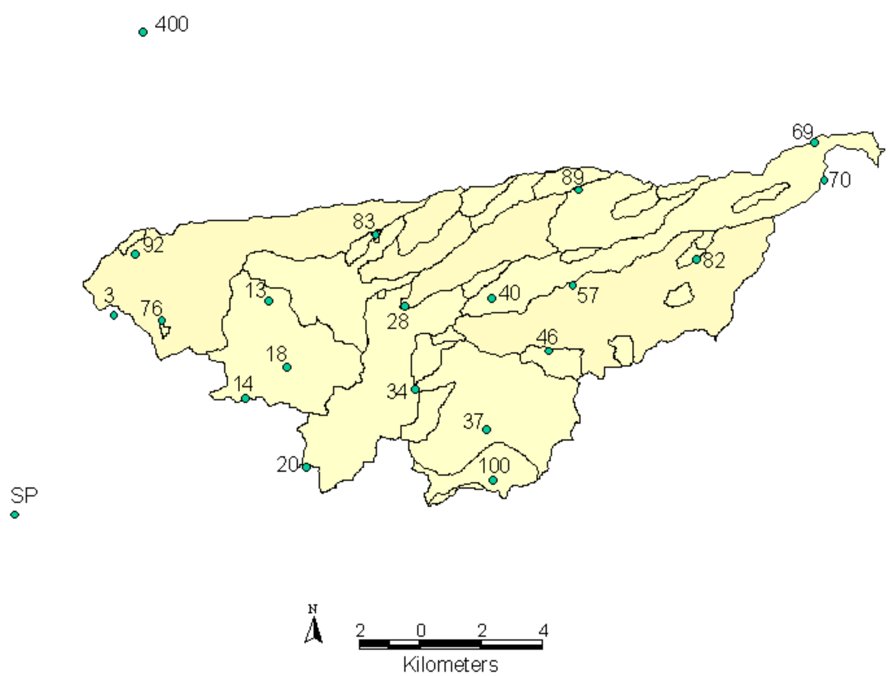


Figure 13. AZ insitu soil moisture network.

RG 83 (Lucky Hills), RG82 (Kendall) and near RG 46 (clay site) each has 3 Vitel probes at 5, 15 and 30 cm depth. The Lucky Hills raingage 83 site is about 100 m west of the NRCS SCAN site (Figure 14), which has Vitel soil moisture probes at 5, 10, 20, 50 and 100 cm. Also nearby the SCAN site is a meteorological station with Dynamax Thetaprobes at 5, 15 and 30 cm, and a proposed soil moisture trench (to be installed 10/02) with TDR probes at 5, 15, 30, 50, 100, 150 and 200 cm. Near the Kendall raingage 82 is a meteorological station with Dynamax Thetaprobes at 5, 15 and 30 cm.

Figure 14. The NRCS SCAN site in the Walnut Gulch Watershed.

RG 400 (Windmill) is located approximately 15 km north of the center of Tombstone, is accessible from the highway and has radio telemetry. The San Pedro site is located in a mesquite bosque about 100 m east of the San Pedro River, approximately 15 km WSW from the center of Tombstone. The sensor is installed at a highly instrumented meteorological/flux/soil research site operated by SWRC. Other soil moisture measurements are made with Campbell Scientific Water Content Reflectometer (WCR) probes (CSI-615).

Table 2. AZ Soil Moisture Network Locations						
Raingage No.	Latitude (Degrees)	Longitude (Degrees)	Northing (m)	Easting (m)	Elev. (m)	Soil Type
3	31.7186	-110.1423	3509566	581265	1253	Off watershed but 'sandy'
13	31.7220	-110.0904	3509986	586181	1327	Monterosa very gravelly fine sandy loam
14	31.6949	-110.0979	3506970	585495	1373	Chiricahua very gravelly clay loam
18	31.7030	-110.0842	3507884	586778	1358	Shiefflin very stony loamy sand
20	31.6746	-110.0764	3504739	587543	1519	Mabray-Chiricahua-Rock-Outcrop Cmplx
28	31.7200	-110.0430	3509803	590669	1369	Graham cobbly clay loam
34	31.6970	-110.0396	3507252	591018	1420	Sutherland very gravelly fine sandy loam
37	31.6843	-110.0150	3505864	593354	1407	Monterosa very gravelly fine sandy loam
40	31.7224	-110.0136	3510092	593449	1392	Baboquivari-Combate complex
57	31.7404	-109.9848	3512115	596162	1462	Tombstone very gravelly fine sandy loam
69	31.7681	-109.9019	3515260	603982	1640	Blacktail gravelly sandy loam
70	31.7569	-109.8984	3514015	604327	1632	Woodcutter gravelly sandy loam
76	31.7169	-110.1271	3509391	582707	1312	Lampshire-Rock Outcrop complex
89	31.7550	-109.9824	3513731	596373	1483	Stronghold-Bernardino complex
92	31.7367	-110.1348	3511576	581955	1251	McAllister Stronghold complex
100	31.6702	-110.0131	3504309	593548	1436	Mabray Rock Outcrop complex
Profile sites						
46	31.7076	-109.9938	3508470	595346	1440	clay
82	31.7343	-109.9420	3511469	600225	1521	Elgin Stronghold complex
83	31.7420	-110.0523	3512232	589765	1367	Luckyhills McNeal complex
Off watershed sites						
400	31.8021	-110.1325	3518828	582120	1266	off watershed but sandy
600	31.6637	-110.1778	3503457	577947	1215	more organic material than other

2.2 Sonora Region

2.2.1 Region Description

Sonora is the second largest state in Mexico (182,032 km2). One of the most important watersheds in the state is the Sonora Watershed (26,708 km2), which includes the Sonora, San Miguel and Zanjon rivers. These rivers are perennial in the upper reaches. The topography is very variable (2200 m asl in the mountains to 0 m asl at the Cortes sea), which results in a highly diverse set of vegetation species.

The experimental site (SO) is located in the near the San Pedro Watershed. It consists of a 50 by 90 km polygon that includes six Easegrid cells (25 by 25 km). This general location is shown in Figure 15.

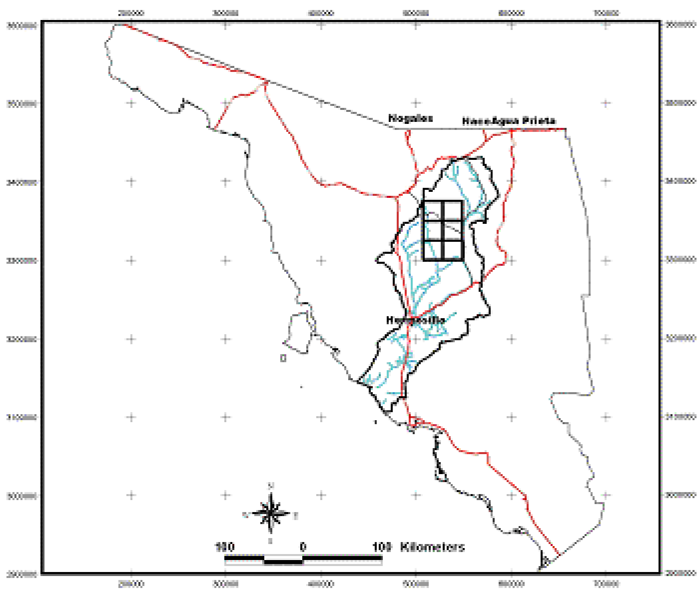


Figure 15. Location of the SO region.

The general climatology of the region is summarized in Figure 16 and Table 3. Approximately 60-70% of precipitation occurs in summer. Cucurpe has the largest winter precipitation (40%).

Table 3. Summary of Climatology for the SO Region.

Site	Tmax (^oC)	Tmin (^oC)	Rainfall (mm)	Tamx_Ext (^oC)	Tmin_Ext (^oC)	Rainfall_Max (mm)
Cucurpe	28.8	10.4	519.7	41.6	-1.5	312 (Jan 1993)
Opodepe	28.7	13.0	477.0	-	-	-
Rayon	30.7	12.1	511.2	41.4	1.0	427 (Oct 2000)
Arizpe	29.2	10.9	435.3	41.5	-0.9	260 (Jul 1977)
Banamichi	30.2	13.1	454.8	43.0	2.3	277 (Jul 1975)

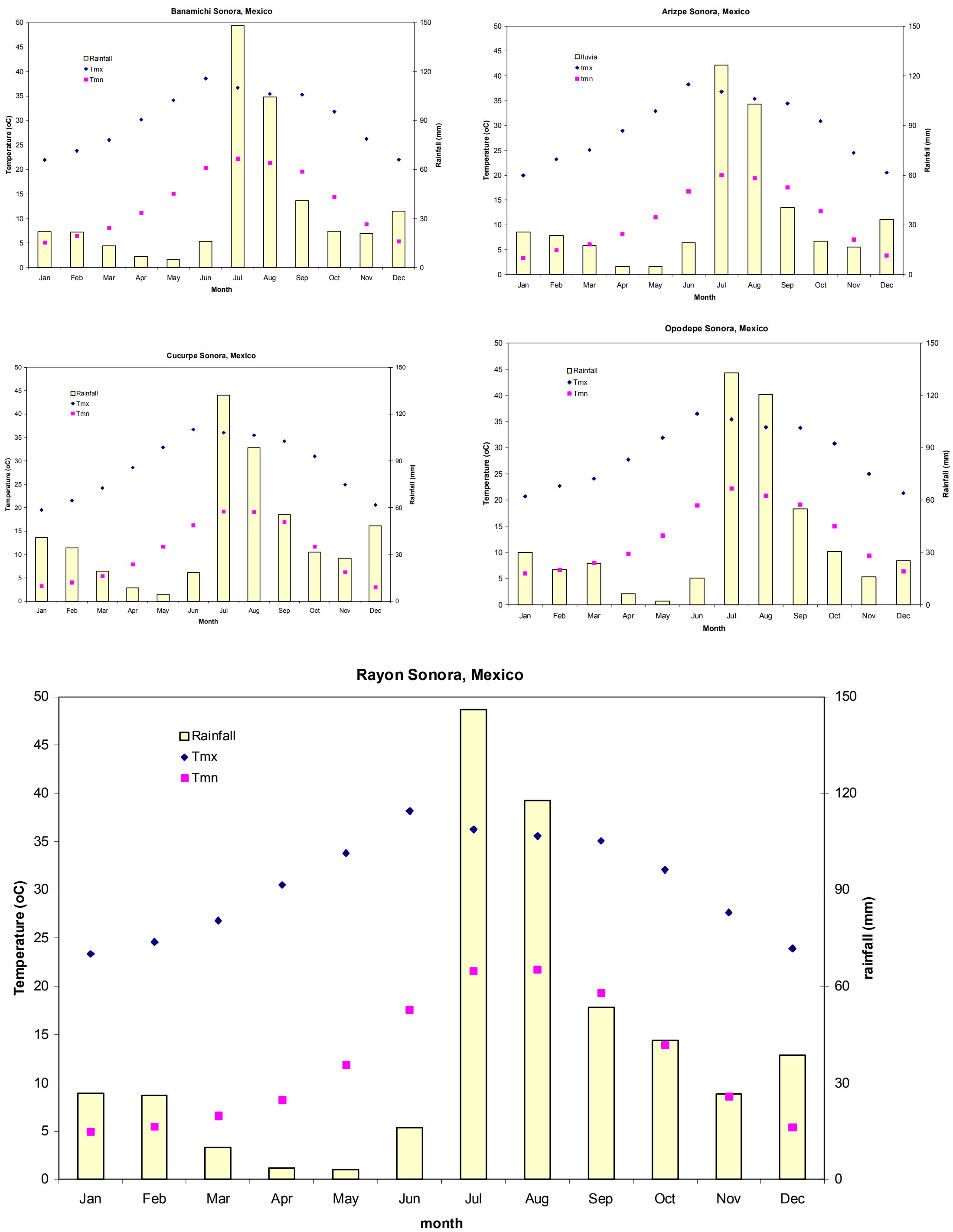


Figure 16. Rainfall and temperature climatology at locations in the SO region.

The vegetation types are shown in Figure 17 and summarized in Table 4. The dominant vegetation types are Scrubland and Scrub subtropical (~33 % each). The subtropical vegetation is located mainly in the south and the scrubland in the north. Conifer vegetation (20%) is situated in the mountain between the Sonora and San Miguel rivers at elevations over 1100 m asl. The grassland shown in Figure 17 does not exist as a pure vegetation type but are mixed with conifers or perennial species. General vegetation features in the southern portion of the region are illustrated in Figure 18.

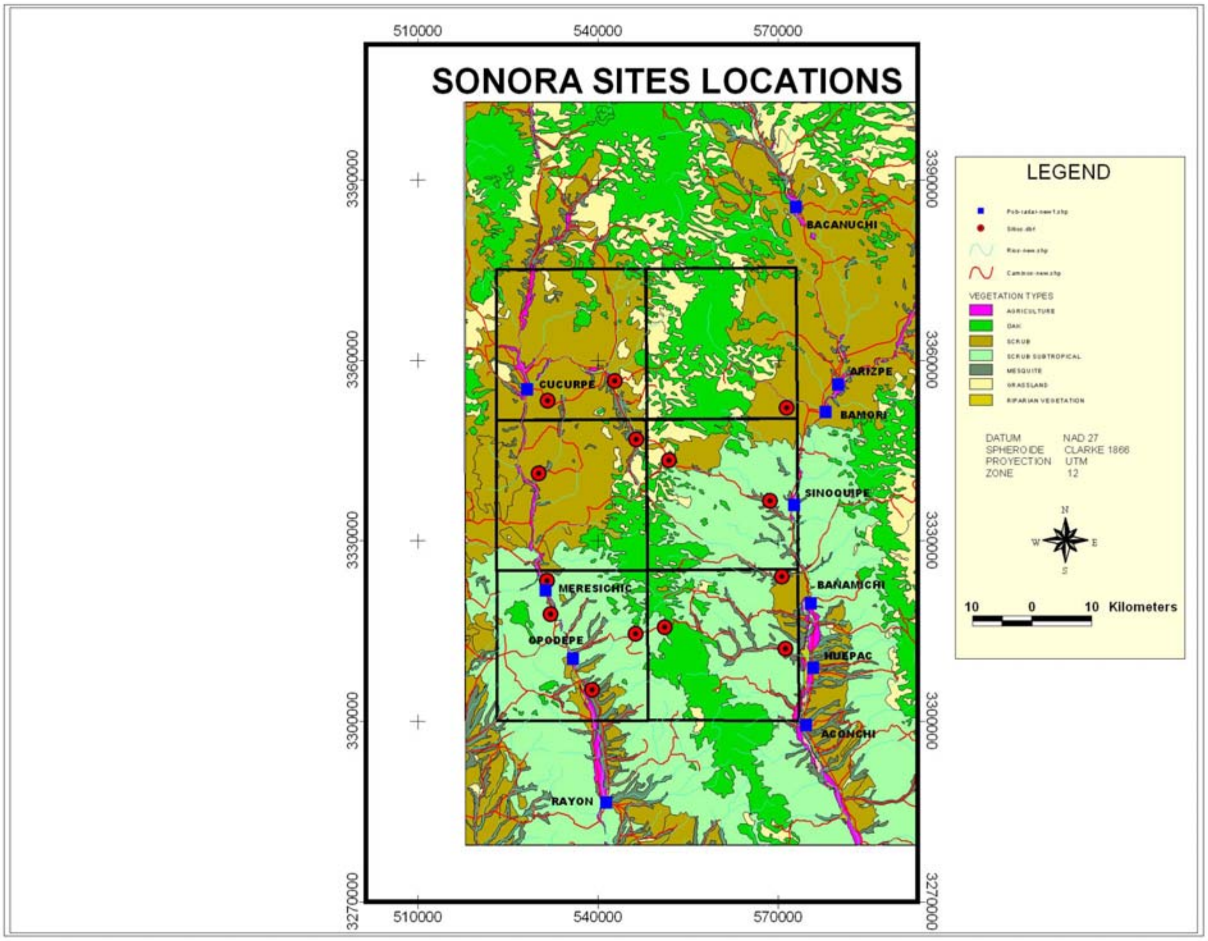


Figure 17. Vegetation types in the SO region.

Table 4. Summary of Vegetation Types in the SO Region.

Vegetation Type	**Area (km^2)**	**Percent (%)**
Agriculture	51.3	1.4
Conifer(Oak)	747.9	19.9
Scrubland	1228.2	32.7
Scrub Subtropical	1258.2	33.5
Mesquite	164.8	4.4
Grassland	301.3	8.0
Riparian Vegetation	9.3	0.2
Total	**3761**	**100**

The soil types are described in the Figure 19 and Table 6. The Litosol class exhibits the more extends distribution of ~50%. These soils are associated with mountains, which is limited in depth by continuous coherent and hard rock within 10 cm of the surface. Regosol, is the second largest class, having no diagnostic horizons, is not depth and normally associated to Litosol.

Figure 18. Photograph taken from SO site 146 on June 2, 2004 showing general landscape features.

Table 5. Summary of Soil Classes in the SO Region.

Soil Class	**Area (km^2)**	**Percent (%)**
Phaeozem	283	7.5
Fluvisol	116	3.1
Litosol	1875	49.9
Planosol	2	0.1
Regosol	998	26.5
Vertisol	23	0.6
Xerosol	326	8.7
Yermosol	137	3.6
Total	**3761**	**100.0**

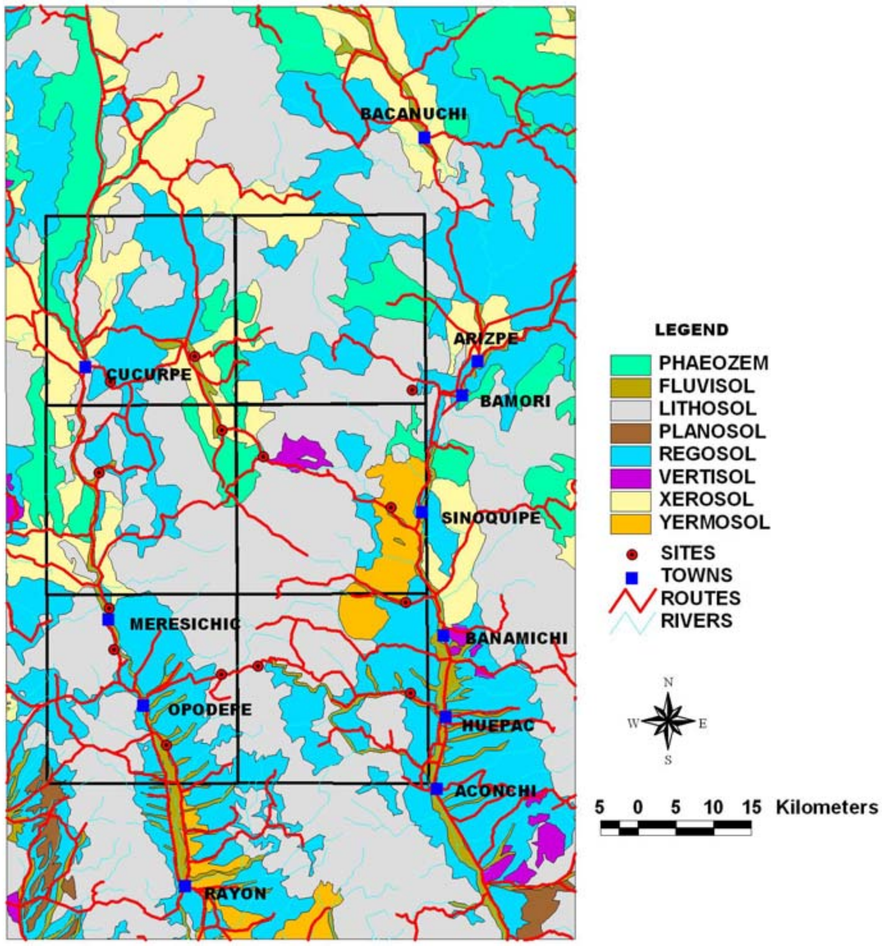


Figure 19. Soils in the SO region.

Topography in the region is highly variable. Figure 20 illustrates the general features of the region.

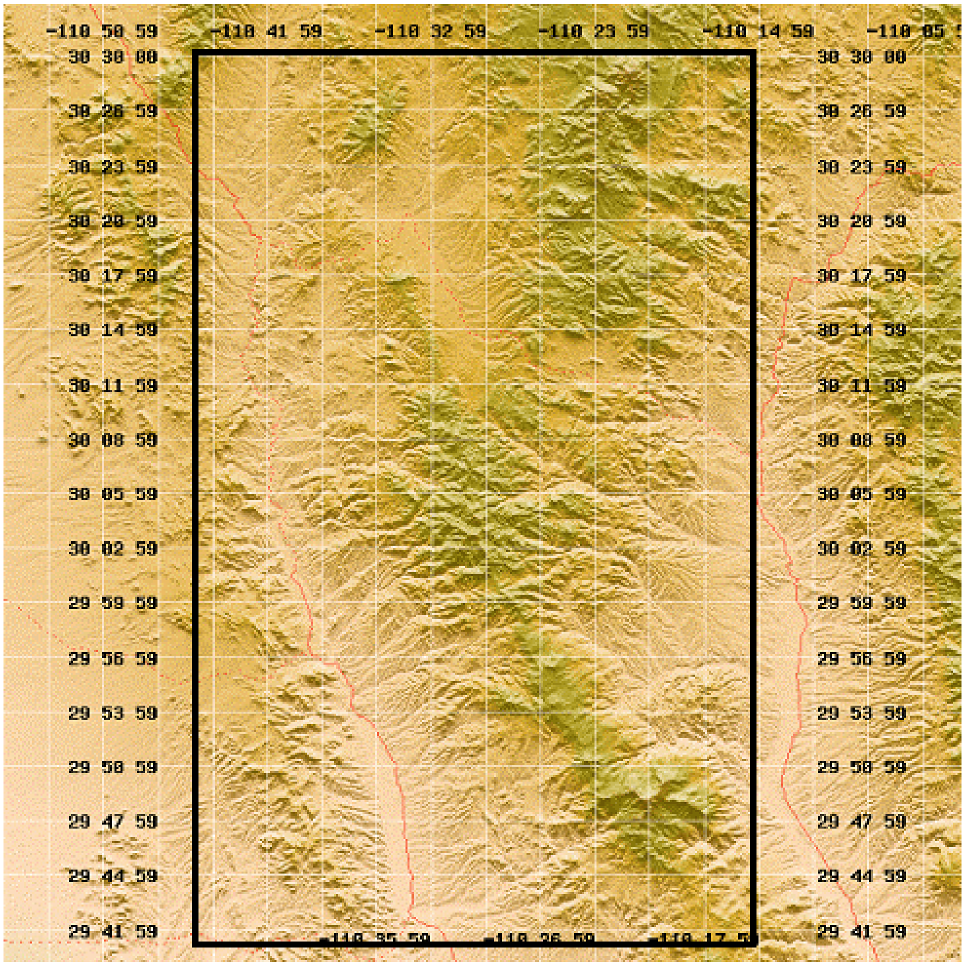


Figure 20. Topography in the SO region.

2.2.2 Network Description

Soil moisture instruments were installed at 14 locations distributed over a 50 by 90 km domain in the SO region. Figure 21 shows the sites and land cover characteristics. Table 6 lists the geographic information for the network sites. Figure 22 illustrates typical land cover conditions at a few sites. Vitel sensors (HYD-50A) were installed along with raingages. All sites include a 5 cm depth sensor. Of these, additional depths will be measured at three locations along with surface temperature (Apogee sensors). All instruments are connected to Campbell Scientific (e.g., CR10X) recorders and reporting at a fixed interval such as 15 minutes. The Vitel probes provide soil moisture and temperature.

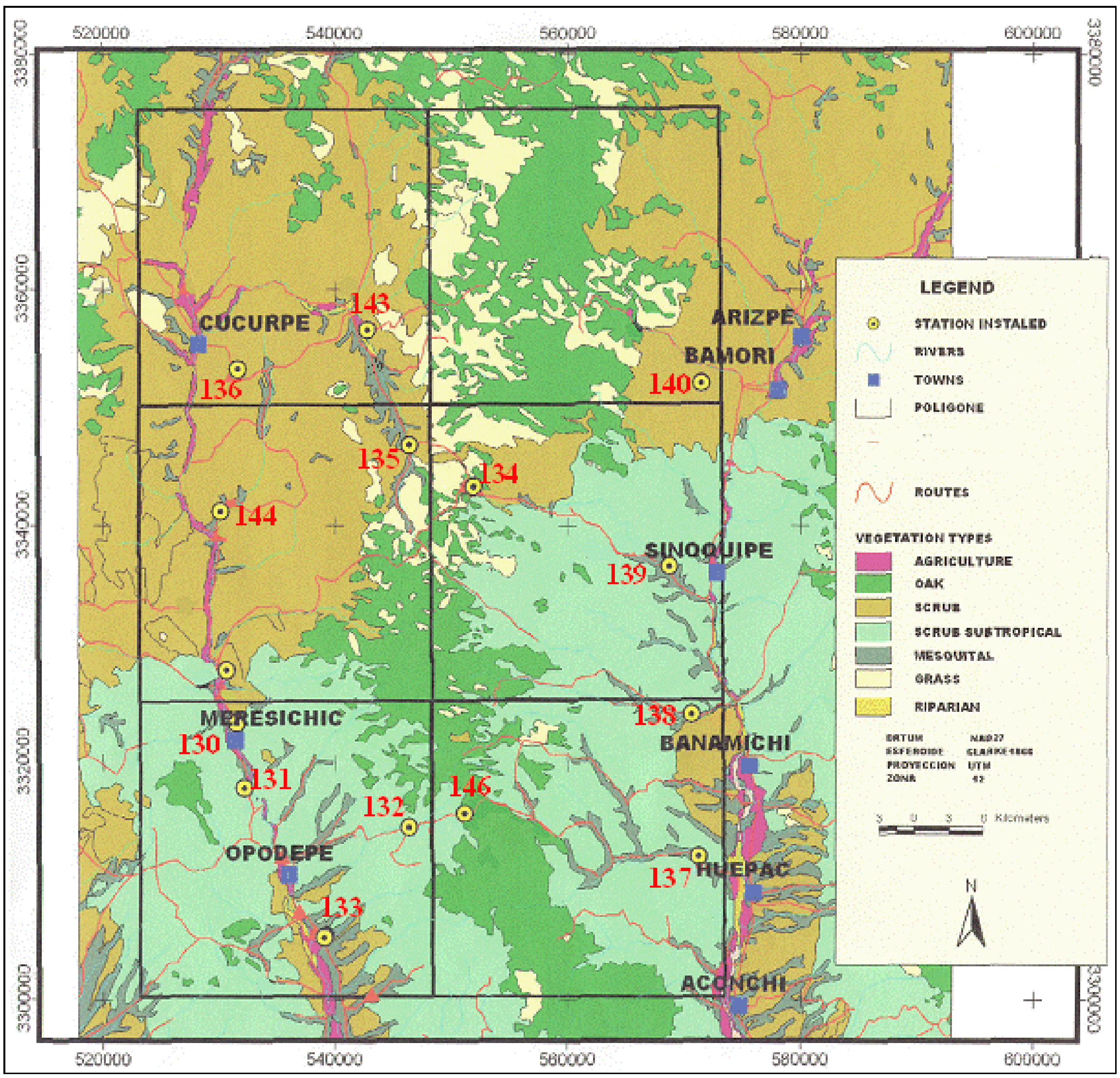


Figure 21. Locations of Sonora Network Sites.

SO network site 134

SO network site 135

SO network site 136

SO network site 146

Figure 22. Examples of Sonora soil moisture network sites.

Table 6. Sonora Network Site Geolocation Information							
Site	Vegetation Type	Location	Latitude (Degrees)	Longitude (Degrees)	Northing (m)	Easting (m)	Elev. (m)
130	Mesquite-Scrubland	1er_sitio	-110.6736	30.0403	3323293	531471	724
131	Scrub-Subtropical	2do sitio	-110.6671	29.9908	3317811	532109	719
132	Scrub-Subtropical	3er sitio	-110.5202	29.9604	3314498	546296	905
133	Scrubland	4to sitio	-110.5954	29.8768	3305202	539068	642
134	Grass-Oak	5to sitio	-110.4612	30.2200	3343285	551854	1180
135	Mesquite	6to_sitio	-110.5177	30.2516	3346767	546401	1044
136	Scrubland	7mo sitio	-110.6712	30.3102	3353210	531611	991
137	Scrub-Subtropical	8vo sitio	-110.2617	29.9371	3312043	571255	660
138	Scrub-Subtropical	9no sitio	-110.2672	30.0455	3324048	570646	722
139	Scrub-Subtropical	10mo sitio	-110.2867	30.1590	3336621	568684	758
140	Scrubland	11vo sitio	-110.2568	30.2982	3352065	571467	1017
143	Mesquite- Oak	12vo sitio	-110.5551	30.3397	3356513	542767	960
144	Scrub-Subtropical	15vo sitio	-110.6869	30.2016	3341164	530135	799
146	Grass-Oak	14vo sitio	-110.4704	29.9705	3315634	551093	1375

note: LON/LAT, spheroide clarke 1866, datum NAD27
UTM, spheroide clarke 1866, zone 12, datum NAD27

3 AIRCRAFT REMOTE SENSING CAMPAIGN

3.1 P-3 Aircraft and Instruments

The P-3 operates from the Navy Patuxent River Air Base in Maryland. It will have the PSR and the 2DSTAR. Whether the GPS sensor system can be integrated has not been determined. The primary mission of the P-3 is to collect high altitude data over the study regions with the PSR instrument. Another very important objective is to collect data with the 2DSTAR over the regions. Mission design and operations are dependent on the PSR and not the 2DSTAR.

Considerations and constraints on mission design (based on SMEX04 specific objectives, and past experience with similar campaigns) include:

- The intensive observing period will be approximately July 12 – August 12, 2004
- An NRL P-3 will be the aircraft platform. The anticipated base of operations will Davis-Monthan Air Force Base in Tucson, AZ
- Daily mission duration should be limited to no more than five hours, but four is preferred
- Coverage will be timed to bracket the afternoon AMSR-E overpass time of 1:30 pm
- Since the rainfall may be localized, including as large a spatial domain as possible will increase the probability of observing a wide range of conditions
- Flightlines will be flown at an altitude of approximately 7300 m above sea level

The two areas chosen for aircraft mapping include the insitu networks previously described. The aircraft coverage boxes are at least 50 km by 75 km in size. As shown in Figure 23 and 24 these were located to coincide with Easegrid cells. The SO region was designed to be slightly larger in order to provide coverage of a land atmosphere study site that will be located near the town of Rayon. Geolocation information is provided in Table 7. Four flightlines would be used to achieve a >50 km swath.

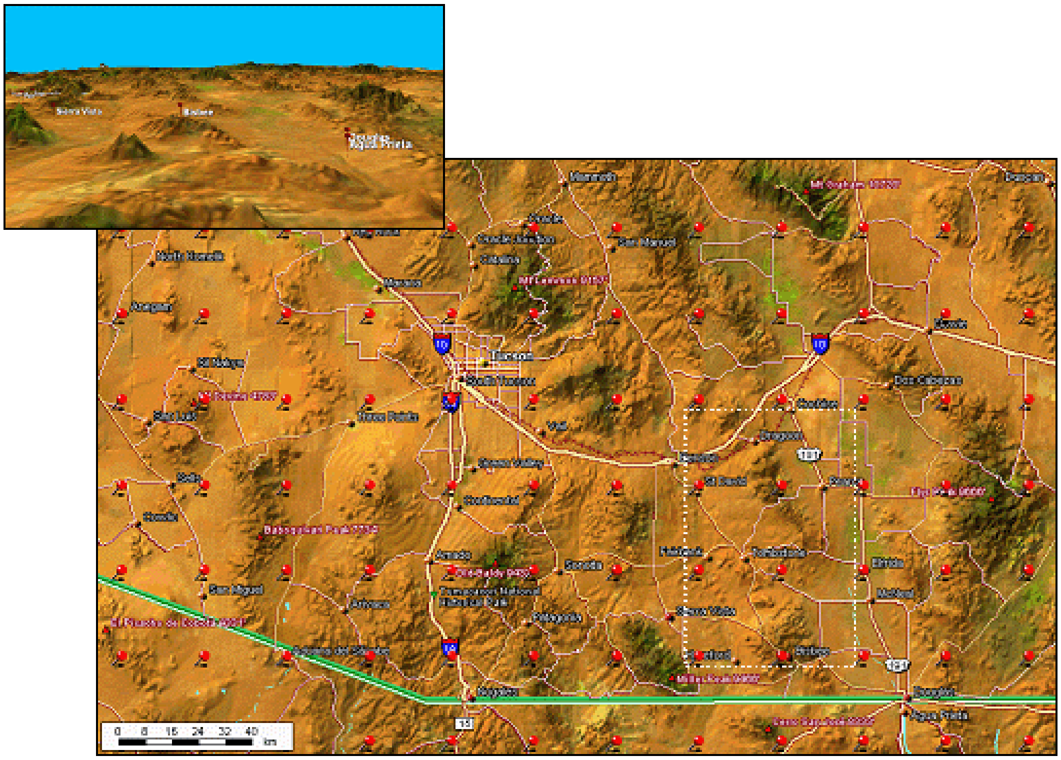


Figure 23. The AZ aircraft mapping area.

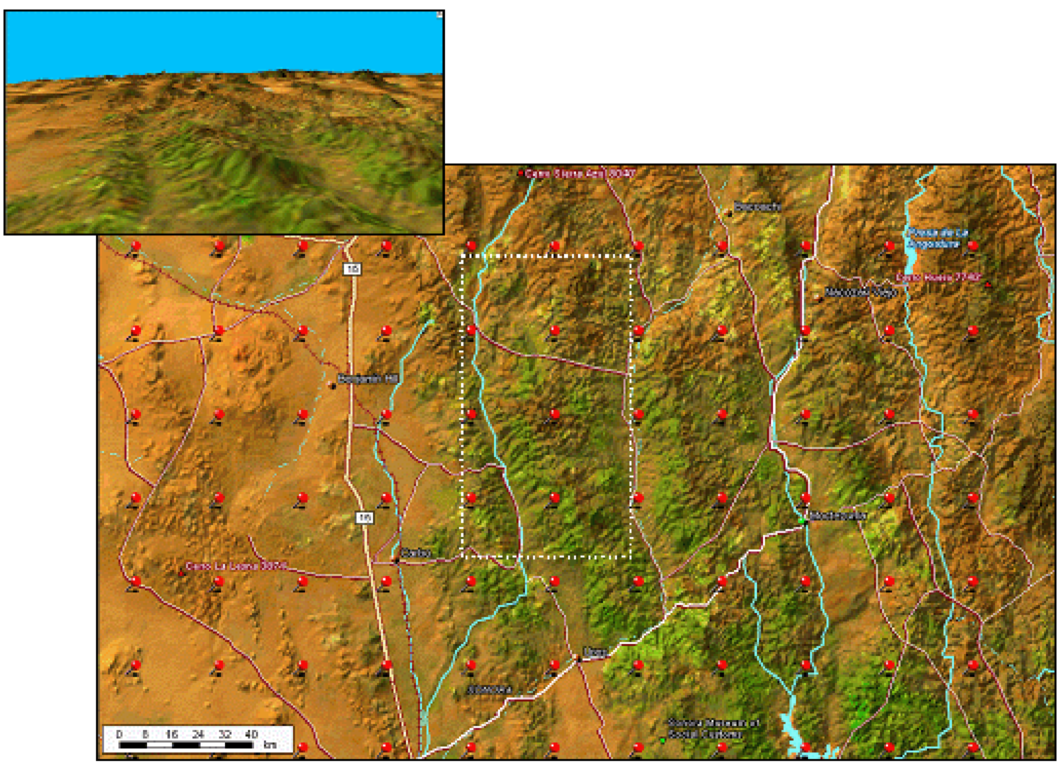


Figure 24. The SO aircraft mapping area.

Table 7. Geolocation Information for SMEX04 P-3 Aircraft Mapping			
Region or Site	Line	Latitude (Deg.)	Longitude (Deg.)
AZ Region	AZ1	31.422	-110.175
		32.112	-110.175
	AZ2	32.112	-110.045
		31.422	-110.045
	AZ3	31.422	-109.915
		32.112	-109.915
	AZ4	32.112	-109.785
		31.422	-109.785
AZ Mapping Box		32.112	-110.239
		31.422	-109.718
Sonora Region	SO1	30.505	-110.695
		29.691	-110.695
	SO2	29.691	-110.565
		30.505	-110.565
	SO3	30.505	-110.435
		29.691	-110.435
	SO4	29.691	-110.305
		30.505	-110.305
SO Mapping Box		30.505	-110.759
		29.691	-110.239

3.1.1 Polarimetric Scanning Radiometer (PSR)

The PSR is an airborne microwave imaging radiometer operated by the NOAA Environmental Technology Laboratory (Piepmeier and Gasiewski 2001) for the purpose of obtaining polarimetric microwave emission. It has been successfully used in several major experiments including SGP99 (Jackson et al. 2002), SMEX02, and SMEX03.

A typical PSR aircraft installation is comprised of four primary components: 1) scanhead, 2) positioner, 3) data acquisition system, and 4) software for instrument control and operation. The scanhead houses the PSR radiometers, antennas, video and IR sensors, A/D sampling system, and associated supporting electronics. The scanhead can be rotated in azimuth and elevation to any arbitrary angle. It can be programmed to scan in one of several modes, including conical, cross-track, along-track, and spotlight. The positioner supports the scanhead and provides mechanical actuation, including views of ambient and hot calibration targets. The PSR data acquisition system consists of a network of four computers that record several asynchronously sampled data streams, including navigation data, aircraft attitude, scanhead position, radiometric voltage, and calibration target temperatures. These streams are available in-flight for quick-look processing.

During SMEX04, the PSR/CX scanhead will be integrated onto the P-3 aircraft in the aft portion of the bomb bay (Figure 25). The PSR/CX scanhead will have the polarimetric channels listed in Table 8. The system will be operated in two imaging modes, both using conical scanning. Mapping characteristics are described in Table 9. Figure 26 shows the results of mapping brightness temperature data from SMEX02 in Iowa.

At the end of a each set of flight lines a steep (~60 degree) port roll will be requested for the purpose of calibrating the PSR radiometers using cold sky looks. Additional details on the PSR not presented here can be found at http://www1.etl.noaa.gov/radiom/psr/

Figure 25. PSR/CX scanhead installed on the NASA P3-B aircraft.

Table 8. PSR/CX Channels for SMEX04		
Frequency (GHz)	Polarizations	Beamwidth
5.82-6.15	V,h	10°
6.32-6.65	V,h	10°
6.75-7.10	v,h,U,V	10°
7.15-7.50	V,h	10°
10.6-10.8	v,h,U,V	7°
10.68-10.70	V,h	7°
9.6-11.5 um IR	V+h	7°

Table 9. PSR Flightline and Mapping Specifications for SMEX04	
Altitude (AGL) in m	7300
Number of parallel flight lines	4
Flight line length (km)	150
Flight line spacing (km)	19
Scan period (seconds)	8
Incidence angle (deg)	55
3-dB footprint resolution	3.0 km at 6 GHz 2.0 km at 10 GHz

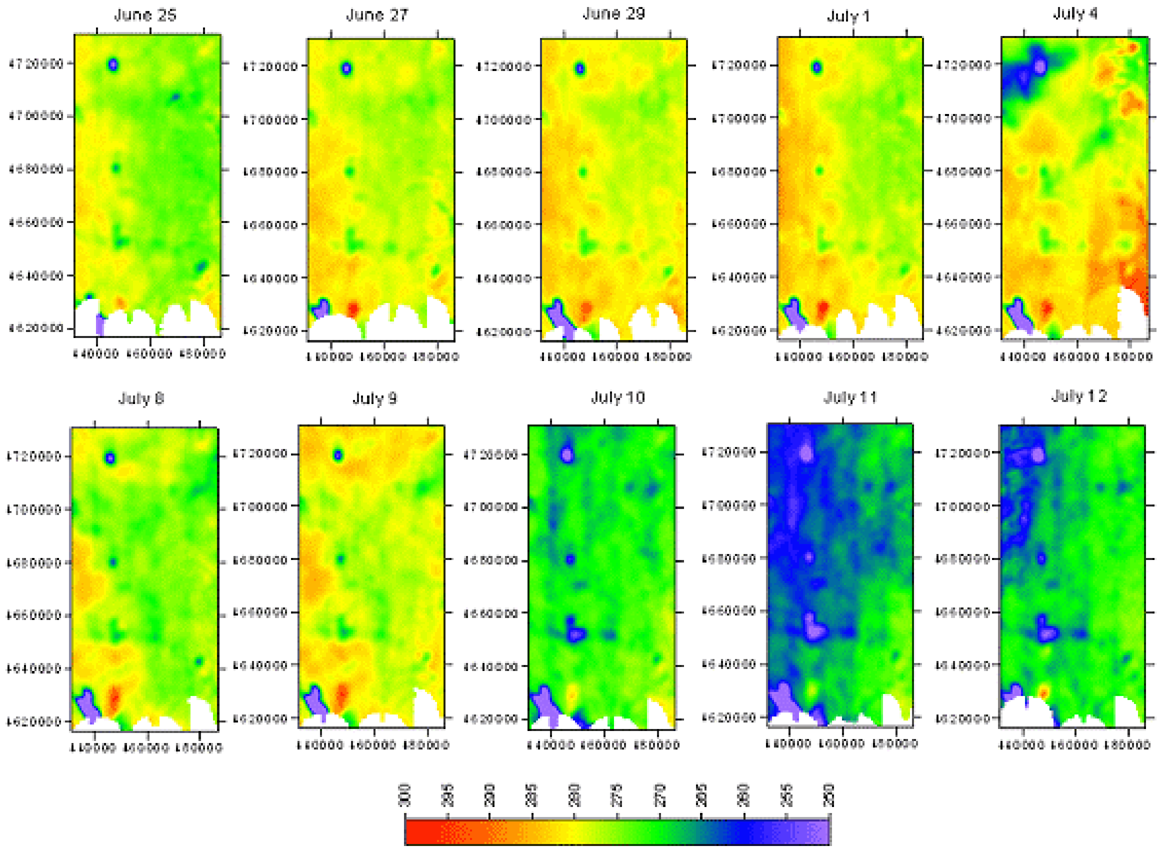


Figure 26. PSR C-band (7.32 GHz) horizontal polarization brightness temperature observations over the SMEX02 region.

3.1.2 L Band Two Dimensional Synthetic Aperture Radiometer (2DSTAR)

Aperture synthesis is an interferometric technique that has the potential to break through the barrier on resolution set by antenna size on future passive microwave instruments in space. The technique has been applied successfully to earth remote sensing using synthesis in one dimension, the L-band radiometer, ESTAR (Le Vine et al. 1990 and 1994). New research is being conducted at the Goddard Space Flight Center and University of Massachusetts to go the next step and demonstrate the potential of aperture synthesis in both dimensions for meeting future remote sensing goals. An aircraft prototype instrument operating at L-band has been developed by this team with ProSensing Inc. and was flown as part of SMEX03. This prototype uses digital correlation and employs a configurable antenna that can be arranged into several thinned array configurations. This same technology will be used in the Soil Moisture Ocean Salinity (SMOS) mission that will be launched by ESA in 2007 (Kerr et al. 2001).

2DSTAR consists of three major subsystems, the antenna array, the RF receiver and the digital processor. The antenna array consists of a rectangular array of dual polarized, patch antennas tuned to L-band (1.413 GHz). In the 2DSTAR instrument, the digital processor averages for a minimum time (on the order of 0.1 second, but adjustable) and then hands the products over to the data system, which stores them and does further averaging as desired. Figure 27 shows the detail of the antenna array. A fully populated, rectangular array of patches is being built. However, only some of the patches will be connected to a receiver. For example, the instrument could operate as a thinned array in the shape of a cross, "+", as shown in Figure 27. A fully populated array is being built so that different configurations can be tried and to minimize effects of mutual coupling by providing a common environment for each patch.

The 2DSTAR instrument has been designed to operate from an aircraft (P-3B) in a nadir looking orientation as shown in Figure 28. Using aperture synthesis, one obtains a map of the entire field-of-view of each individual antenna in each integration cycle. This allows for a number of processing options. For example, it allows one to arrange the pixels in the equivalent of a conical scan as illustrated in Figure 28 or to use the multiple looks that one obtains with each pixel as it moves through the field-of-view to reduce noise by averaging or to retrieve additional data. In the later case, because a given pixel is viewed at different incidence angles as it moves through the field of view, it may be possible to retrieve parameters such as attenuation in the canopy in the case of a soil covered with a layer of vegetation, which is the approach used with SMOS (Kerr et al. 2001).

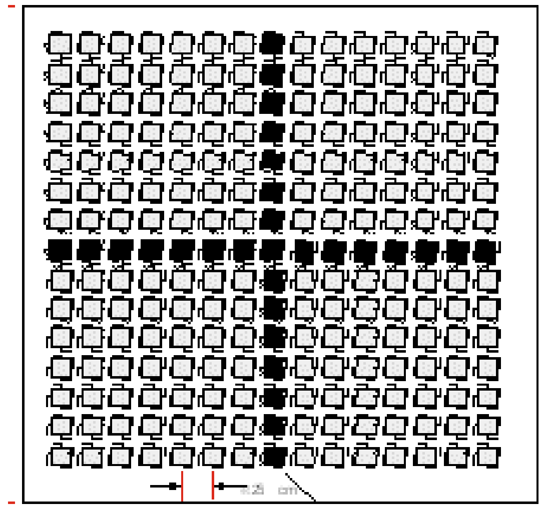


Figure 27. Antenna patch array shown configured for measuring using a cross “+” configuration.

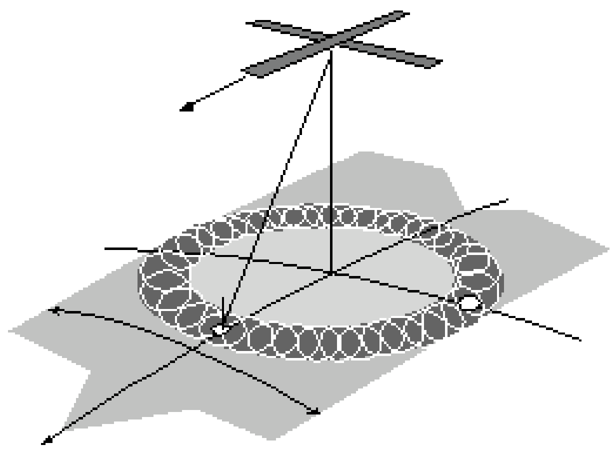


Figure 28. A thinned array in a nadir-pointing mode illustrating the potential for conical scanning.

3.2 ER-2 and AVIRIS

The Airborne Visible Infrared Imaging Spectrometer (AVIRIS) is a whisk-broom type hyperspectral instrument developed and operated by NASA's JPL (http://aviris.jpl.nasa.gov). AVIRIS has 224 contiguous bands from about 400 nm to about 2500 nm wavelength, with each band being about 10 nm wide. Actual wavelengths for each band are determined by annual calibration at JPL. The swath is 614 pixels and the instantaneous field of view is 1 milliradian, so pixel size and swath depend on aircraft altitude. When flown on the NASA ER2 aircraft from the NASA Dryden Flight Research Center (Edwards, CA; http://www.dfrc.nasa.gov), the altitude is 20 km (high-altitude data), the pixel size is 20 m and the swath is 12 km. The ER-2 aircraft was requested for the SMEX04 experiment to cover each of the study areas in their entirety with six flight lines. An additional line was added to the AZ area to include coverage of a portion of the Riparian area of the San Pedro River. Flight lines for the ER-2 are listed in Table 10. Color infrared photos (1:40,000 scale) are usually acquired at the same time by the ER-2.

Table 10. SMEX04 ER-2 AVIRIS Flight Lines

	Line No.	Latitude (Deg.)	Longitude (Deg.)	Northing (m)	Easting (m)
Arizona	1	31.6333	-110.3358	3499982	562986
		32.3333	-110.3358	3577574	562510
Arizona	2	32.1167	-110.2403	3553624	571668
		31.4217	-110.2403	3476588	572205
Arizona	3	31.4217	-110.1450	3476655	581263
		32.1167	-110.1450	3553691	580658
Arizona	4	32.1167	-110.0494	3553767	589677
		31.4217	-110.0494	3476729	590350
Arizona	5	31.4217	-109.9542	3476811	599399
		32.1167	-109.9542	3553850	598658
Arizona	6	32.1167	-109.8586	3553941	607678
		31.4217	-109.8586	3476902	608486
Arizona	7	31.4217	-109.7633	3477000	617544
		32.1167	-109.7633	3554041	616669
Sonora	1	30.5550	-110.7153	3380321	527305
		29.6910	-110.7153	3284580	527543
Sonora	2	29.6910	-110.6319	3284603	535612
		30.5550	-110.6319	3380344	535303
Sonora	3	30.5550	-110.5433	3380375	543801
		29.6910	-110.5433	3284634	544184
Sonora	4	29.6910	-110.4494	3284673	553268
		30.5550	-110.4494	3380415	552807
Sonora	5	30.5550	-110.3608	3380460	561304
		29.6910	-110.3608	3284717	561840
Sonora	6	29.6910	-110.2775	3284765	569899
		30.5550	-110.2775	3380509	569293

The flight crew at Dryden for the ER2 will go over the day's weather predictions for all sites, and pick the highest priority site with clear weather for that day's flight. Hence, due to weather conditions, sites with high priority may not be flown, although this should not be a problem for a morning overflight during the SMEX04 experiment. The data will be processed by the AVIRIS Data Facility at JPL, and will arrive about 3 to 6 months after the overflight. Each study area (Arizona or Sonora) will result in 6.3 Gigibytes of raw data.

The data are provided as "at-sensor radiance," so atmospheric correction is made with one of several available computer programs, which use atmospheric absorption features at various wavelengths to estimate atmospheric transmittance. Calibration targets of known reflectance are useful for further correction of the radiances to surface reflectances. The data are geometrically corrected using a "Geometric Lookup Table," which is determined by GPS location and aircraft inertial data.

4 SATELLITE OBSERVING SYSTEMS

4.1 Advanced Microwave Scanning Radiometer (AMSR-E)

AMSR-E on Aqua (http://wwwghcc.msfc.nasa.gov/AMSR/) was launched in May 2002. Algorithm development and validations of AMSR-E soil moisture products are very important components of SMEX04 (Njoku et al. 2003).

As shown in Table 11, the lowest frequency is 6.9 GHz (C band). However, studies indicate that there is widespread radio frequency interference (RFI) in the C band channels (Li et al. 2003). Therefore, it is likely that the most useful channels for soil moisture will be those operating at the slightly higher X band. The viewing angle of AMSR is a constant 55^o. Details on AMSR-E can be found at http://wwwghcc.msfc.nasa.gov/AMSR/. Figure 29 illustrates the type of coverage provided by AMSR-E. Aqua has an overpass time of 1:30 am and pm local time. Aqua overpasses for the SMEX04 regions are summarized in Table 12.

Table 11. AMSR-E Characteristics

Frequency (GHz)	Polarization	Horizontal Resolution (km)	Swath (km)
6.925	V, H	75	1445
10.65	V, H	48	1445
18.7	V, H	27	1445
23.8	V, H	31	1445
36.5	V, H	14	1445
89.0	V, H	6	1445

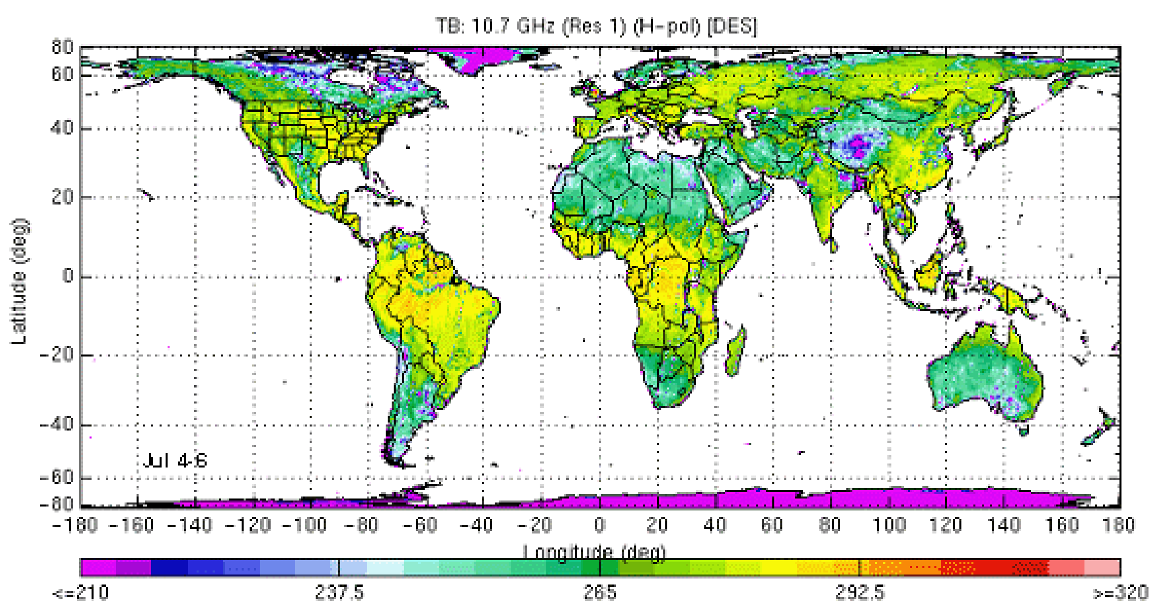


Figure 29. Example of AMSR-E brightness temperature image, three-day global composite.

Table 12. SMEX04 Aqua AMSR-E Coverage Dates and Times			
Month	Day	Hour (Local)	Minute
7	13	2	31
7	13	13	32
7	15	2	19
7	15	13	20
7	17	2	7
7	17	13	7
7	18	13	50
7	19	1	54
7	20	2	37
7	20	13	38
7	22	2	25
7	22	13	26
7	24	2	13
7	24	13	13
7	25	13	56
7	26	2	0
7	27	13	44
7	28	2	48
7	29	2	31
7	29	13	31
7	31	2	18
7	31	13	19
8	2	2	6
8	2	13	7
8	3	13	50
8	4	1	54
8	5	2	37
8	5	13	37
8	7	2	24
8	7	13	25
8	9	2	12
8	9	13	13
8	10	13	55
8	11	2	0
8	12	13	43

Aqua includes several other instruments of potential value to investigators in the 2004 experiment:

- The Atmospheric Infrared Sounder (AIRS) is a high-resolution instrument, which measures upwelling infrared (IR) radiances at 2378 frequencies ranging from 3.74 and 15.4 micrometers.

- The Advanced Microwave Sounding Unit (AMSU) is a passive scanning microwave radiometer consisting of two sensor units, A1 and A2, with a total of 15 discrete channels operating over the frequency range of 50 to 89 GHZ. The AMSU operates in conjunction with the AIRS and HSB instruments to provide atmospheric temperature and water vapor data both in cloudy and cloud-free areas.
- Clouds and the Earth's Radiant Energy System (CERES) is a broadband scanning radiometer, with three detector channels, 0.3 to 5.0 micrometers, 8.0 to 12.0 micrometers and 0.3 to 50 micrometers.
- Moderate Resolution Imaging Spectroradiometer (MODIS) is a passive imaging spectroradiometer. The instrument scans a cross-track swath of 2330 km using 36 discrete spectral bands between 0.41 and 14.2 micrometers.

4.2 Tropical Rainfall Mapping Mission (TRMM) Microwave Imager (TMI)

All of the study areas in SMEX04 fall within the coverage domain of the Tropical Rainfall Mapping Mission (TRMM) Microwave Imager (TMI). It is a five-channel, dual-polarized, passive microwave radiometer with a viewing angle of 52.75^{o} (see Table 13). Coverage is available between + and - 38 degrees latitude. The lowest frequency of the TMI is about half that of the SSM/I. Other interesting features of the TMI are its significantly higher spatial resolution (at 19 GHz the TMI is 18 km as opposed to the SSM/I 60 km). For most of the southern U.S. it is possible to obtain coverage every day. The nominal coverage times during SMEX04 are summarized in Tables 14 and 15. There are multiple overpasses each day, however, the time of observation varies. During the first week of the experiment the times match up with the aircraft mapping. Details on this satellite can be found by starting at the following web site http://trmm.gsfc.nasa.gov/data/. There are several sources for these data and products. TMI data have been used in previous soil moisture mapping applications (Jackson and Hsu 2001, Bindlish et al. 2003).

Table 13. TMI Characteristics

Frequency (GHz)	Polarization	Horizontal Resolution (km)	Swath (km)
10.7	V, H	38	790
19.4	V, H	18	790
21.3	H	16	790
37.0	V, H	10	790
85.5	V, H	4	790

Table 14. TMI Coverage of AZ Region During SMEX04							
Month	Day	Hour (Local)	Minute	Month	Day	Hour (Local)	Minute
7	12	9	20	7	28	4	17
7	12	12	35	7	29	12	06
7	13	8	24	7	29	1	44
7	13	10	02	7	29	3	22
7	13	11	40	7	29	5	00
7	14	7	29	7	30	12	49
7	14	9	07	7	30	4	04
7	14	10	44	7	30	23	53
7	14	12	22	7	31	3	08
7	15	8	11	7	31	22	57
7	15	11	26	8	1	12	35
7	16	7	15	8	1	2	13
7	16	10	31	8	1	23	40
7	17	6	20	8	2	1	17
7	17	7	58	8	2	2	55
7	17	9	35	8	2	22	44
7	17	11	13	8	3	1	59
7	18	7	02	8	3	21	49
7	18	8	40	8	4	1	04
7	18	10	17	8	4	20	53
7	19	6	07	8	4	22	31
7	19	9	22	8	5	12	08
7	20	5	11	8	5	1	46
7	20	8	26	8	5	21	35
7	21	4	15	8	5	23	13
7	21	5	53	8	6	12	50
7	21	7	31	8	6	20	40
7	21	9	09	8	6	11	55
7	22	4	58	8	7	19	44
7	22	6	35	8	7	22	59
7	22	8	13	8	8	18	48
7	23	4	02	8	8	20	26
7	23	7	17	8	8	22	04
7	24	3	06	8	8	23	42
7	24	4	44	8	9	19	31
7	24	6	22	8	9	21	08
7	25	2	11	8	9	22	46
7	25	3	49	8	10	18	35
7	25	5	26	8	10	21	50
7	25	7	04	8	11	17	39
7	26	2	53	8	11	19	17
7	26	4	31	8	11	20	55
7	26	6	08	8	12	16	44
7	27	1	58	8	12	18	22
7	27	5	13	8	12	19	59
7	28	1	02	8	12	21	37
7	28	2	40				

Table 15. TMI Coverage of SO Region During SMEX04							
Month	Day	Hour (Local)	Minute	Month	Day	Hour (Local)	Minute
7	13	8	22	7	29	0	04
7	13	13	16	7	29	4	57
7	14	7	26	7	30	0	46
7	14	12	20	7	30	4	02
7	15	8	09	7	30	23	51
7	15	11	24	7	31	3	06
7	16	7	13	7	31	22	55
7	16	10	29	8	1	3	49
7	17	6	18	8	1	21	59
7	17	11	11	8	2	2	53
7	18	5	22	8	2	22	42
7	18	10	15	8	3	1	57
7	19	6	04	8	3	21	46
7	19	9	20	8	4	20	51
7	20	5	09	8	5	1	44
7	20	10	02	8	5	17	55
7	21	4	13	8	6	12	48
7	21	9	06	8	6	20	37
7	22	3	17	8	6	23	53
7	22	8	11	8	7	19	42
7	23	4	00	8	8	0	35
7	23	7	15	8	8	18	46
7	24	3	04	8	8	23	40
7	24	7	58	8	9	17	50
7	25	2	09	8	9	22	44
7	25	7	02	8	10	18	33
7	26	1	13	8	10	21	48
7	26	6	06	8	11	17	37
7	27	1	55	8	11	22	31
7	27	5	11	8	12	16	42
7	28	1	00	8	12	21	35
7	28	5	53				

4.3 Special Sensor Microwave Imager (SSM/I)

SSM/I satellites have been collecting global observations since 1987. The SSM/I satellite data can only provide soil moisture under very restricted conditions because the frequencies (see Table 16) were not selected for land applications (Jackson 1997, Jackson et al. 2002, Teng et al. 1993). The viewing angle of the SSM/I is 53.1^{o}.

There may be as many as four satellites with the SSM/I on board in operation during SMEX04. The local ascending equatorial crossing times of the three currently available satellites are F13 (17:54), F14 (20:46), and F15 (21:20). F16 (07:54) was launched in October 2003. SSM/I data are useful in some aspects of algorithm development and provide a cross reference to equivalent channels on the TMI and AMSR instruments. SSM/I data are freely available to users through http://www.saa.noaa.gov/. As in past experiments, the data will be subset and repackaged for this experiment.

Table 16. SSM/I Characteristics			
Frequency (GHz)	Polarization	Spatial Resolution (km)	Swath (km)
19.4	H and V	69 x 43	1200
22.2	V	60 x 40	1200
37.0	H and V	37 x 28	1200
85.5	H and V	15 x 13	1200

4.4 Coriolis WindSat

WindSat is a multi-frequency polarimetric microwave radiometer developed by the U.S. Navy and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office (IPO) (http://www.pxi.com/windsat). It is one of the two primary instruments on the Coriolis satellite. The Coriolis satellite was successfully launched on January 6, 2003, with an expected life cycle of three years.

The WindSat radiometer operates at nominal frequencies of 6.8, 10.7, 18.7, 23.8, and 37 GHz. Using a conically-scanned 1.83 m offset parabolic reflector with multiple feeds, the WindSat covers a 1025 km active swath (based on an altitude of 830 km) and provides two looks at both fore (1025 km) and aft (350 km) views of the swath. The nominal earth incidence angle (EIA) is in the range of 50 – 55 degrees. The inclination of the WindSat orbit is 98.7 degrees. It has a sun synchronous polar orbit with an ascending node at 6:00 PM and a descending node at 6:00 AM.

The WindSat has similar frequencies to the Advanced Microwave Scanning Radiometers on the Earth Observing System (AMSR-E), with the addition of full polarization for 10.7, 18.7 and 37.0 GHz and the lack of 89.0 GHz. The characteristics of the WindSat radiometer are listed in Table 17. The methods developed for algorithm development and validations for AMSR-E during SMEX04 may be applied to WindSat with minimal modifications. The coverage dates and times of WindSat during SMEX04 are summarized in Table 18.

Table 17. Characteristics of WindSat.				
Frequency (GHz)	Polarization	Incidence Angle (Deg.)	Footprint (Km)	Fore/Aft Swath (Km)
6.8	V, H	53.5	40 x 60	1025/350
10.7	V, H, U 4	49.9	25 x 38	1025/350
18.7	V, H, U, 4	55.3	16 x 27	1025/350
23.8	V ,H	53.0	12 x 20	1025/350
37.0	V, H, U 4	53.0	8 x 13	1025/350

4.5 Envisat Advanced Synthetic Aperture Radar (ASAR)

The Envisat satellite was launched by the European Space Agency in March 2002 (http://envisat.esa.int/). It is designed to provide Earth observations using a suite of remote sensing instruments. Of particular interest to soil moisture and hydrology is the inclusion of the Advanced Synthetic Aperture Radar (ASAR) that will provide both continuity to the ERS-1 and ERS-2 mission SARs and next generation capabilities. Envisat also has a visible and near infrared imaging system called MERIS that is of interest in SMEX04. Envisat has a sun synchronous polar orbit. The exact repeat cycle for a specific scene and sensor configuration is 35 days.

Table 18. SMEX04 WindSat Coverage Dates and Times

Month	Day	Hour (Local)	Minute
7	12	6	34
7	12	18	53
7	13	6	17
7	13	17	35
7	17	6	47
7	17	18	6
7	18	6	30
7	18	17	49
7	19	6	13
7	19	17	31
7	22	7	1
7	22	18	19
7	23	6	43
7	23	18	2
7	24	6	26
7	24	17	44
7	28	6	57
7	28	18	15
7	29	6	39
7	29	17	58
7	30	6	22
7	30	17	40
8	3	6	52
8	3	18	11
8	4	6	35
8	4	17	54
8	5	6	18
8	5	17	36
8	9	6	48
8	9	18	7
8	10	6	31
8	10	17	49
8	11	6	13
8	11	17	32

The ASAR is a C band instrument, which is the same frequency as the ERS instrument. Unlike the ERS satellites that had a fixed angle of incidence (23^o) ASAR has a wider range of choices that can provide more frequent coverage and a variety of incidence angles. ASAR Image Mode will provide data acquisition in the seven different swath positions listed in Table 19, giving incidence angles ranging from 15° to 45°. IS1 is closest to the track of the satellite and IS7 is furthest away. When acquired simultaneously, each IS views a different area across track. In order to get all IS positions for the same ground location a series of days is required.

Table 19. Specifications for ASAR Image Mode Swaths.

Image Swath	Swath Width (km)	Ground, position from nadir (km)	Incidence Angle Range
IS1	105	187 - 292	15.0 - 22.9
IS2	105	242 - 347	19.2 - 26.7
IS3	82	337 - 419	26.0 - 31.4
IS4	88	412 - 500	31.0 - 36.3
IS5	64	490 - 555	35.8 - 39.4
IS6	70	550 - 620	39.1 - 42.8
IS7	56	615 - 671	42.5 - 45.2

The other new feature of ASAR of interest for soil moisture is the alternating polarization (AP) mode. In this mode two polarization combinations (ERS had only VV) can be obtained (VV and HH, HH and HV, or VV and VH). It is anticipated that this additional information will enhance soil moisture retrieval. Swath width is nominally 100 km and the product pixel size is 30 m.

There are a limited number of data products available in dual polarization mode. Those of interest include: Alternating Polarization Mode Precision Image (APP) and Alternating Polarization Ellipsoid Geocoded Image (APG). Each will be a nominal 100 x 100 km scene with a pixel spacing of 12.5 x 12.5 m and a pixel size of 30 x 30 m. The APG is resampled to a North orientation and georectified.

In general the VV-VH combination is preferred for soil moisture. IS2 provides continuity of the ERS observations. IS1-IS3 may be better for minimizing roughness effects while IS4-IS6 may provide more vegetation information. Figure 30 is a color composite image of IS2 data collected over the Walnut Gulch watershed in September 2003 and Figure 31 covers the SO region.

Data takes must be scheduled and are limited to approved investigations. Coverage of all SMEX04 sites concurrent with ground data collection will be requested. The data sets ordered are listed in Table 20.

Another instrument on Envisat that may be of value in SMEX04 is the MEdium Resolution Imaging Spectrometer Instrument (MERIS). This is a 68.5^{o} field-of-view pushbroom imaging spectrometer that measures the solar radiation reflected by the Earth, at a ground spatial resolution of 300 m, in 15 spectral bands (412.5, 442.5, 490, 510, 560, 620, 665, 681.25, 705, 753.75, 760, 775, 865, 890, and 900 nm), programmable in width and position, in the visible and near infra-red. The instrument has a very wide swath, which results in frequent coverage. MERIS allows global coverage of the Earth in 3 days. MERIS data cannot be obtained at the same time as ASAR image products. MERIS data have been requested for daytime passes on June 29, July 2, 5, 8, 12, 15,18, 21, and 24 at a nominal time of 11:00 am CDT.

Table 20. Envisat ASAR AP Data Ordered for SMEX04					
Region	Month	Day	Hour(Local)	Minutes	IS Mode
AZ	6	15	10	27	2
	7	20	10	27	2
	8	24	10	27	2
	9	28	10	27	2
	7	4	10	30	2
	8	8	10	30	2
	9	12	10	30	2
	10	17	10	30	2
	6	14	22	10	2
	7	19	22	10	2
	8	23	22	10	2
	9	27	22	10	2
	8	5	10	24	3
	7	17	10	21	4
	8	2	10	19	5
	7	14	10	16	6
SO	7	20	10	27	2
	7	4	10	30	2
	8	8	10	30	2
	9	12	10	30	2
	10	17	10	30	2
	7	17	10	22	4
	8	2	10	19	5
	7	14	10	16	6

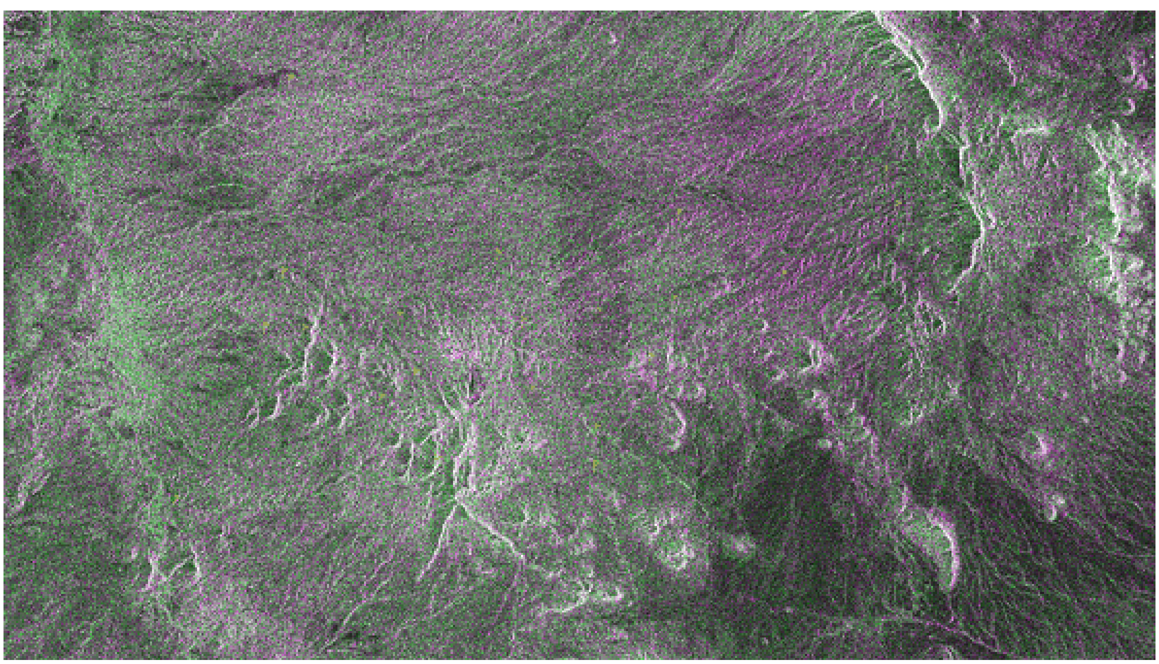


Figure 30. ASAR image of the Walnut Gulch Watershed on September 9, 2003. VV was assigned purple and VH green.

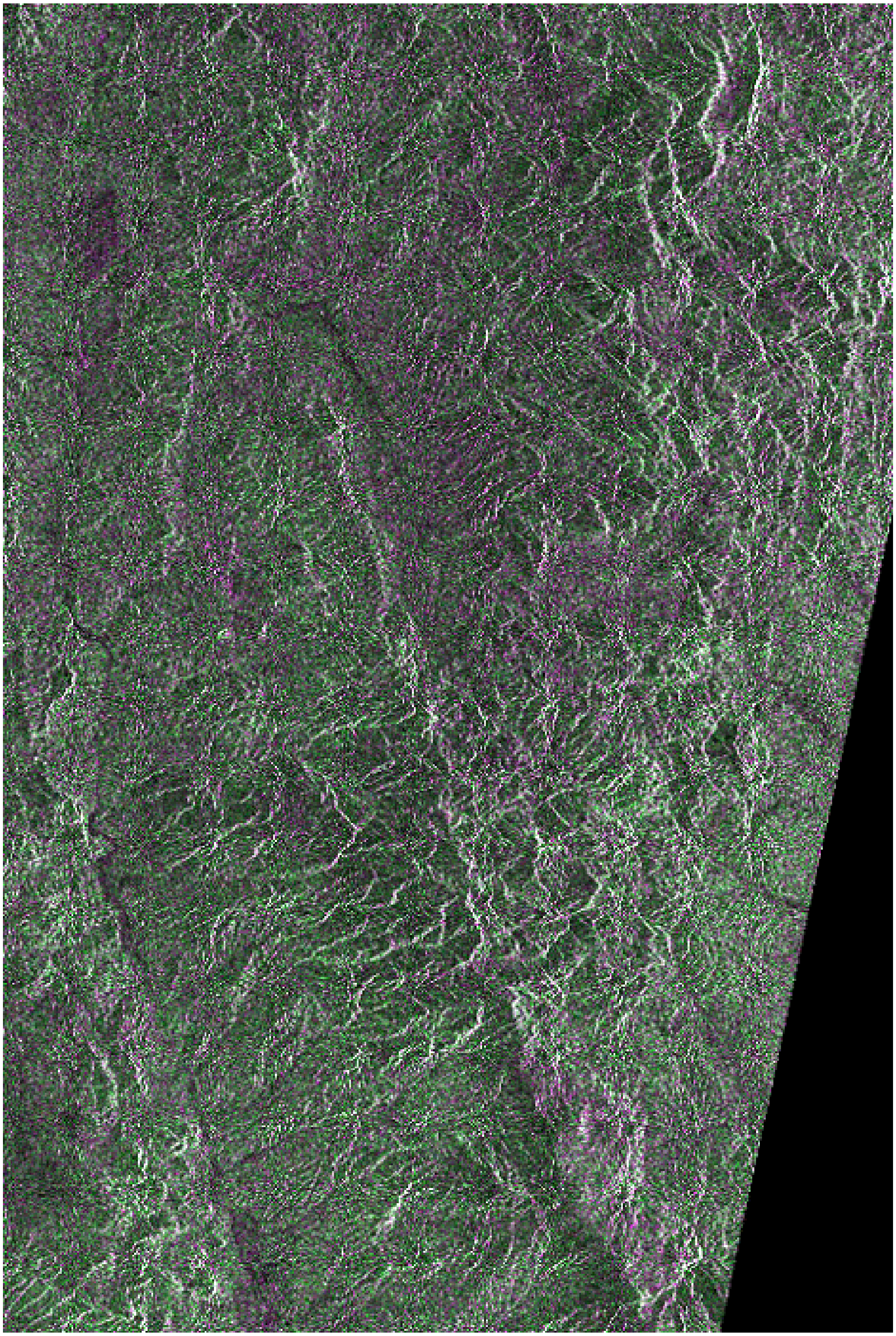


Figure 31. ASAR image of the Walnut Gulch Watershed on April 25, 2004. VV was assigned purple and VH green.

4.6 Terra Sensors

The NASA Terra spacecraft (http://terra.nasa.gov/About/) includes several instruments of value to the soil moisture investigations proposed here. Of particular interest are the Moderate-resolution Imaging Spectroradiometer (MODIS) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER).

MODIS is on both the Terra and Aqua satellites (http://modis.gsfc.nasa.gov). The Terra satellite has a descending orbit that crosses the equator about 10:30 AM local time and the Aqua satellite has an ascending equatorial crossing time of 1:30 PM local time. Coverage of a single location varies with the orbital path, so coverage can be either daily or every other day. The angle of incidence varies depending on the orbital path from -55° to 55° for a swath of 2330 km. The bands of MODIS are listed in Table 21. MODIS coverage during SMEX04 is included in the calendar in Section 9.

Table 21. MODIS Bands.

Primary Use	Band(s)	Wavelength	Pixel Size
Vegetation Index	1	620-670 nm	250 m
Vegetation Index	2	841-876 nm	250 m
	3	459-479 nm	500 m
	4	545-565 nm	500 m
Vegetation H_2O	5	1230-1250 nm	500 m
Vegetation H_2O	6	1628-1652 nm	500 m
	7	2105-2155 nm	500 m
Ocean Color	8-16	405-877 nm	1000 m
Atmospheric H_2O	17-19	890-965 nm	1000 m
Thermal	20-36	3.660-14.385 :m	1000 m

Most of the imagery from MODIS are provided by the NASA GSFC DAAC as data products. Surface reflectance for bands 1-7 are provided as product MOD 09, which has: (1) an atmospheric transmittance correction; (2) a view angle correction for BRDF; and (3) a cloud mask. The data are not corrected for topography.

Other MODIS data products of interest are land cover type (MOD 12), vegetation indices (MOD 13), leaf area index (MOD 15), evapotranspiration (MOD 16), net primary production (MOD 17), and land surface temperature (MOD 11), which are composited to produce a cloud-free image at 1000 m pixel resolution every 10 days.

ASTER provides high resolution visible (VIR, short wave infrared (SWIR), and thermal infrared (TIR) data on request (see Table 22). Coverage has been requested for the regional study areas for July 5, July 21, and August 6.

Table 22. Characteristics of the ASTER Sensor Systems			
System	Channel	Spectral Range (μm)	Spatial Resolution (m)
VIR	1	0.52-0.60	15
	2	0.63-0.69	
	3N	0.78-0.86	
	3B	0.78-0.86	
SWIR	4	1.60-1.70	30
	5	2.145-2.185	
	6	2.185-2.225	
	7	2.235-2.285	
	8	2.295-2.365	
	9	2.360-2.430	
TIR	10	8.125-8.475	90
	11	8.475-8.825	
	12	8.925-9.275	
	13	10.25-10.95	
	14	10.95-11.65	

4.7 Landsat Thematic Mapper

The Landsat Thematic Mapper (TM) satellites collect data in the visible and infrared regions of the electromagnetic spectrum. Data are high resolution (30 m) and are very valuable in land cover and vegetation parameter mapping. Additional details on the Landsat program and data can be found at http://landsat7.usgs.gov/programdesc.html.

At the present time Landsat 5 is still in operation and, following a problem, Landsat 7 is now providing modified products. An instrument malfunction occurred onboard Landsat 7 on May 31, 2003. The problem was caused by failure of the Scan Line Corrector (SLC), which compensates for the forward motion of the satellite. The problem is permanent and results in an up to 25 % data loss per scene. The Landsat 7 Enhanced Thematic Mapper Plus (ETM+) is still capable of acquiring useful image data with the SLC turned off, particularly within the central portion of any given scene (about 22 km). These data are still acquired and are referred to as "SLC-off" mode.

SLC Enhanced products are also now available that use interpolation schemes to fill missing data gaps. These can be based on pre-loss of SLC scenes or other dates.

The Landsat paths and row reference numbers for SMEX04 are 35/38 AZ region and 35/39 SO region. Relevant coverage dates are Landsat 5 (July 13, July 29, August 14) and Landsat 7 (July 5, July 21, August 6).

4.8 SeaWinds QuikSCAT

SeaWinds is a radar scatterometer on QuikSCAT. It was launched in 1999 and was designed to measure near-surface wind speed over the Earth's oceans. SeaWinds uses a rotating dish antenna with two spot beams that sweep in a circular pattern. The antenna spins at a rate of 18 rpm, scanning two pencil-beam footprint paths at incidence angles of 46° (H-pol) and 54° (V-pol). The antenna radiates microwave pulses at a frequency of 13.4 GHz across broad regions on Earth's surface with an 1800 km swath.

QuikSCAT is in a sun-synchronous, 803-kilometer, circular orbit with a local equator crossing time at the ascending node of 6:00 A.M. +/- 30 minutes. The SeaWinds antenna footprint is an ellipse approximately 25-km in azimuth by 37-km in the look (or range) direction. There is considerably overlap of these footprints, with approximately 8-20 of these ellipses with centers in a 25x25 km box on the surface. Signal processing provides commandable variable range resolution of approximately 2- to 10-km. The nominal resolution is approximately 6 km—an effective range gate of 0.5 msec. Additional information is available at http://podaac.jpl.nasa.gov/quikscat/qscat_doc.html.

Gridded (0.2x0.2 degree) daily observations are available. Documentation is available at http://podaac.jpl.nasa.gov:2031/DATASET_DOCS/dLongSigBrw.html, and data orders can be placed through linked pages. Non-binned data are available, on tapes and through FTP, from the PO.DAAC (http://podaac.jpl.nasa.gov/quikscat/qscat_data.html).

5 SOIL MOISTURE FIELD CAMPAIGN DESIGN

Ground based soil moisture measurements will be made for a variety of investigations. Three different sampling schemes will be employed; regional, watershed, and topographic gradient.

The goal of regional soil moisture sampling is to provide a reliable estimate of the volumetric soil moisture (VSM) mean and variance within a single satellite passive microwave footprint (~50 km) and multiple EASE-grid 25 km cells at the nominal time of the Aqua AMSR-E overpass (1330 local standard time). The exact center location and orientation of the satellite footprint will vary with each overpass. How this will be integrated for each of the study regions will vary but should be based upon the general model shown in Figure 30, which has been used in SMEX02 and SMEX03. A grid of sites will be sampled each day that covers a domain of approximately 50 km by 75 km. The exact size and layout will vary at each of the regional study areas. Spacing will be nominally 8-10 km between sites. The layout should attempt to provide a minimum of six sites within each 25 km square EASE-grid cell. A single location within each of these sites will be sampled with replication. As noted, these measurements are used primarily to support the AMSR based microwave investigations; therefore, the regional sampling will be conducted within a +/- two-hour time window of the satellite overpass.

The primary measurement made will be the 0-6 cm dielectric constant at a single location in each site using the Theta Probes (TP). Dielectric constant is converted to volumetric soil moisture using a calibration equation. There are built in calibration equations, however, we will develop field and site specific relationships using supplemental either volumetric soil moisture or gravimetric soil moisture and bulk density sampling. Each sampling day, a gravimetric sampling device (scoop tool) will be used to extract a single sample of the 0-3 cm and 3-6 cm soil layers. Gravimetric soil moisture (GSM) will be converted to VSM using independently sampled bulk density and rock fraction information. The composite set of VSM samples and TP dielectric constants will be used to calibrate the TP for each site. Figure 32 illustrates how regional sampling was performed in SMEX02.

Regional sampling in the AZ region will be complemented with more intensive watershed sampling at raingage locations within the Walnut Gulch watershed. The same protocols used for regional sampling will be employed. This data set will be used for more extensive analysis of the aircraft soil moisture products. It is anticipated that as many as 64 raingage locations will be sampled.

The third type of sampling, topographic gradient, will be performed along a transect in the SO region. Sampling design will balance length of transect against density and resources. The sampling protocol will be the same as that used in regional sampling.

Site characterization will be performed one time for each site. This will include bulk density, surface roughness, rock fraction, Geolocation, and general vegetation features. More extensive vegetation characterization will be performed at a subset of all sites.

Soil moisture sampling will be performed daily and is not dependent on whether the aircraft flies that day. As described in the previous section, there is satellite coverage nearly every day.

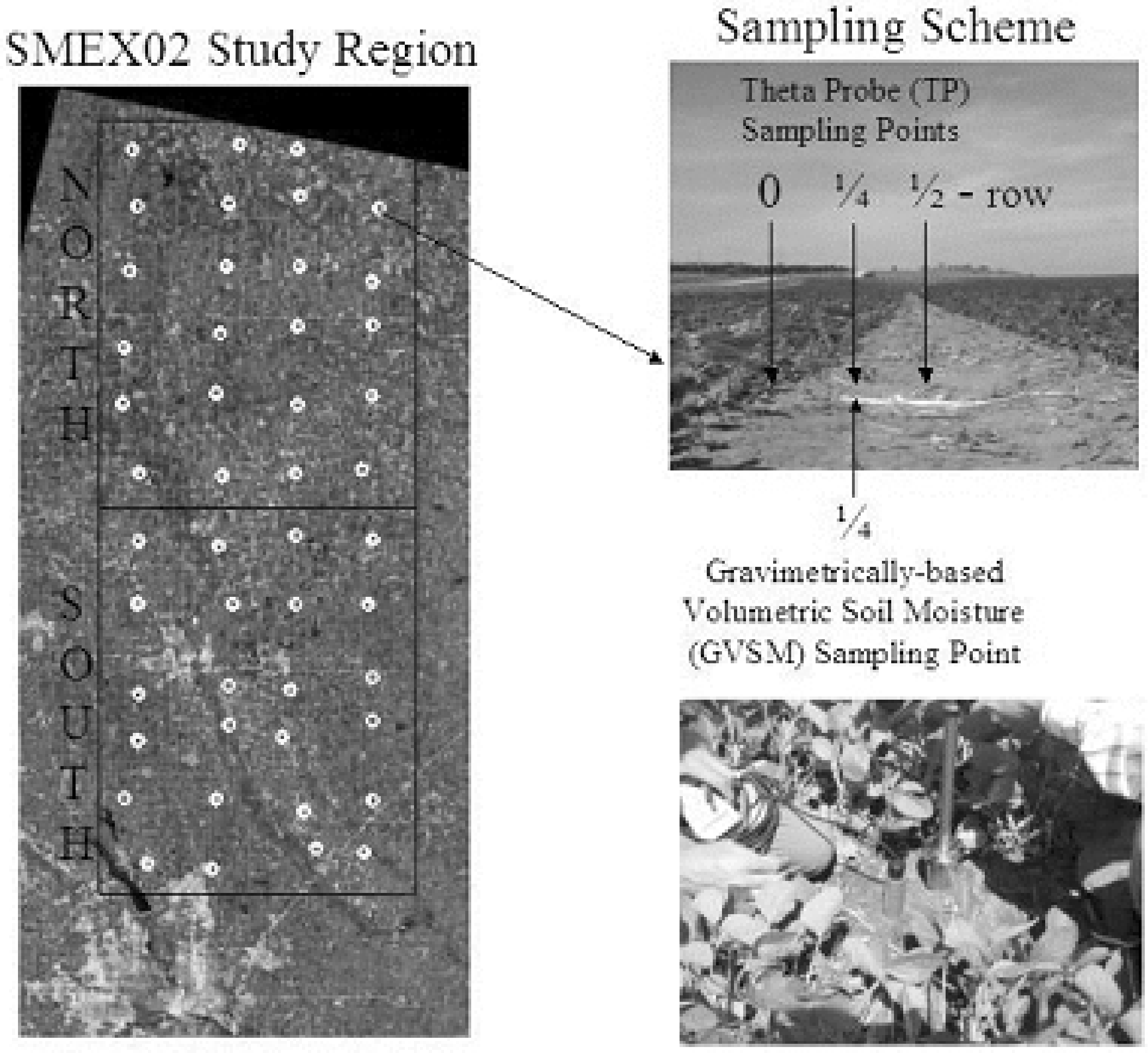


Figure 32. Regional soil moisture sampling in SMEX02.

5.1 Ground Sampling Arizona (AZ)

All sites selected for AZ regional sampling are listed in Table 23 and shown in Figure 33. It is anticipated that this will involve five teams. Table 24 lists the WG watershed sampling sites. These are plotted in Figure 34. Four teams will sample these.

Table 23. AZ Regional Sampling Sites

Site	Land Ownership	Latitude (Degrees)	Longitude (Degrees)	Northing (m) Zone 12	Easting (m) Zone 12
1	Az State	32.07679	-110.0737	3549323	587415
2	Az State	32.05222	-110.0425	3546625	590388
3	Az State	32.01286	-110.1613	3542169	579202
4	Az State	31.97106	-110.1793	3537523	577539
5	Az State	31.97512	-110.1323	3538007	581980
6	Az State	31.93011	-110.1957	3532972	576029
7	Az State	31.91936	-110.1299	3531828	582258
8	Az State	31.88141	-110.1833	3527582	577235
9	Az State	31.80210	-110.1324	3518828	582124
10	Az State	31.74510	-110.1244	3512517	582932
11	Az State	31.72383	-110.0910	3510185	586110
12	Az State	31.65869	-110.1342	3502931	582081
13	Az State	31.55146	-110.1780	3491014	578018
14	Az State	31.46930	-110.2322	3481870	572933
15	Az State	31.43739	-110.2174	3478343	574368
16	Az State	31.44022	-110.0850	3478754	586943
17	Az State	32.05037	-109.8990	3546549	603933
18	Jim Grim	32.02537	-109.8646	3543812	607211
19	Az State	32.08080	-109.7653	3550059	616517
20	Az State	31.97673	-109.7797	3538507	615294
21	Az State	31.90517	-109.7800	3530574	615351
22	Az State	31.91859	-109.8475	3531992	608951
23	Az State	31.91991	-109.9144	3532073	602631
24	Az State	31.78647	-110.0312	3517177	591716
25	Az State	31.87518	-109.9080	3527121	603286
26	Az State	31.86239	-109.8132	3525797	612267
27	Az State	31.79086	-109.8125	3517869	612415
28	Az State	31.71995	-109.7986	3510023	613822
29	Az State	31.74947	-109.9117	3513183	603070
30	Az State	31.73614	-109.9976	3511627	594952
31	Az State	31.68560	-110.0344	3505993	591511
32	Az State	31.60039	-110.0463	3496539	590472
33	Az State	31.53878	-110.0843	3489679	586916
34	Az State	31.45936	-109.9458	3480994	600156
35	Federal (BLM)	31.40945	-109.9625	3475447	598621
36	Az State	31.41933	-109.8021	3476697	613855
37	Az State	31.47112	-109.8223	3482417	611873
38	Ron Bemis	31.59486	-109.6986	3496266	623463
39	H. Harshburger	31.59912	-109.8234	3496604	611614
40	Fred Davis	31.63177	-109.9091	3500138	603453

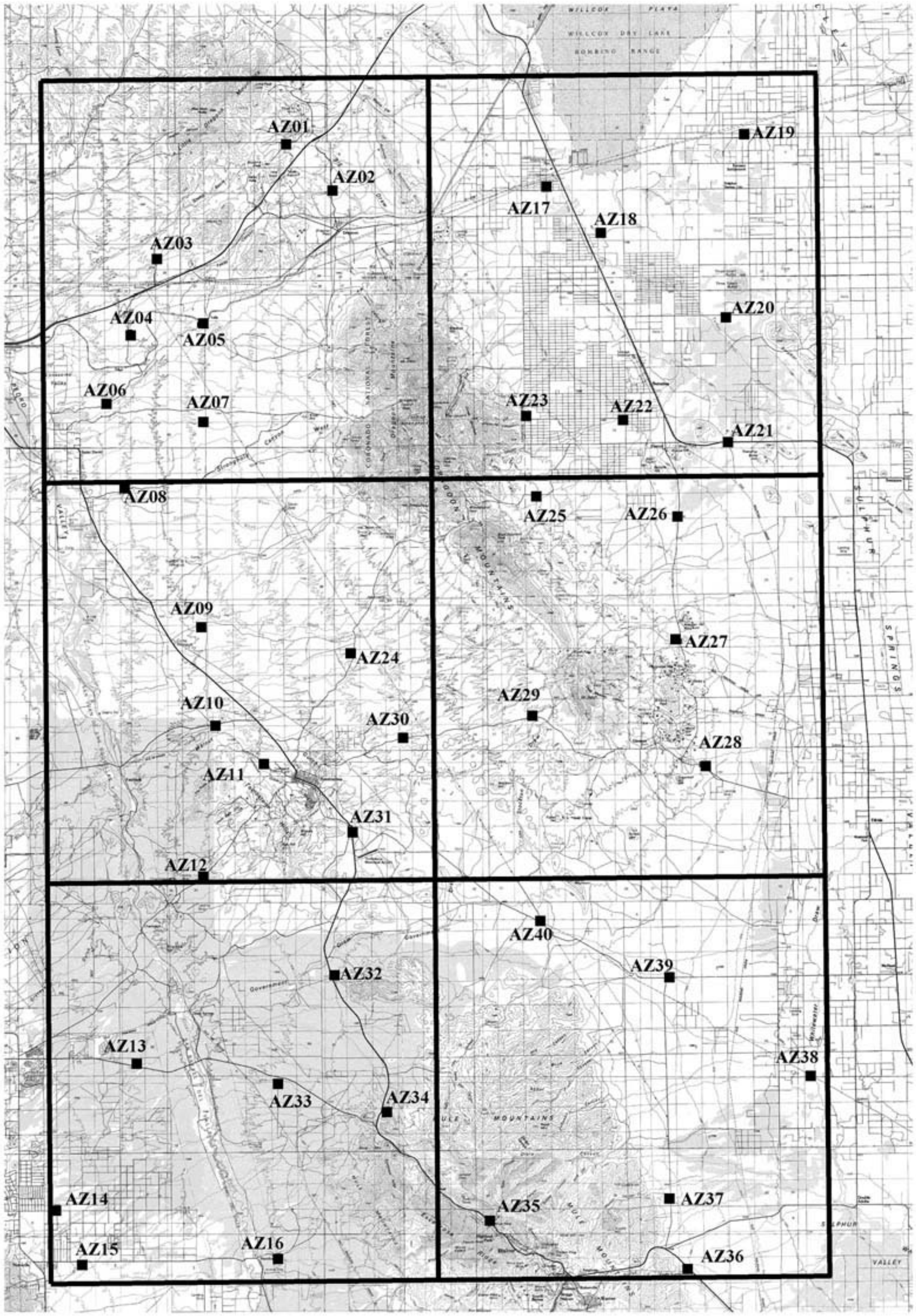


Figure 33. AZ regional sampling design.

Table 24. WG Watershed Sampling Sites				
Raingage	Latitude	Longitude	Northing (m)	Easting (m)
	(Degrees)	(Degrees)	Zone 12	Zone 12
RG1	31.73026	-110.1536	3510850	580177
RG2	31.74104	-110.1428	3512053	581187
RG3	31.72043	-110.1428	3509768	581204
RG5	31.72937	-110.1275	3510770	582649
RG7	31.74762	-110.1082	3512808	584459
RG8	31.73474	-110.1154	3511375	583788
RG9	31.71678	-110.1071	3509391	584592
RG10	31.70745	-110.1107	3508354	584265
RG11	31.74595	-110.0929	3512635	585909
RG12	31.73481	-110.0989	3511396	585356
RG14	31.69684	-110.0983	3507187	585442
RG15	31.75079	-110.0765	3513185	587458
RG16	31.73716	-110.0832	3511669	586839
RG17	31.72406	-110.0709	3510226	588021
RG18	31.70496	-110.0849	3508098	586710
RG19	31.69238	-110.0730	3506713	587845
RG20	31.67640	-110.0770	3504939	587480
RG21	31.75248	-110.0593	3513386	589091
RG22	31.73813	-110.0673	3511789	588341
RG23	31.73244	-110.0594	3511164	589101
RG25	31.69372	-110.0523	3506879	589809
RG26	31.68157	-110.0637	3505522	588736
RG28	31.72172	-110.0434	3509990	590624
RG29	31.70897	-110.0312	3508586	591791
RG30	31.68560	-110.0344	3505993	591511
RG32	31.73696	-110.0241	3511695	592441
RG33	31.72633	-110.0312	3510511	591778
RG35	31.69396	-110.0328	3506921	591655
RG38	31.75340	-109.9999	3513538	594711
RG40	31.72418	-110.0145	3510286	593360
RG41	31.70414	-110.0156	3508064	593275
RG42	31.67597	-110.0223	3504936	592673
RG43	31.76140	-109.9932	3514431	595343
RG45	31.72418	-110.0001	3510299	594726
RG46	31.70930	-109.9943	3508655	595289
RG47	31.69468	-110.0052	3507025	594270
RG48	31.68220	-109.9915	3505653	595587
RG49	31.67856	-110.0032	3505240	594481
RG50	31.76568	-109.9771	3514919	596864
RG52	31.73893	-109.9813	3511950	596490
RG53	31.71707	-109.9866	3509523	596008
RG54	31.75704	-109.9629	3513974	598218
RG56	31.74212	-109.9618	3512322	598334
RG57	31.72841	-109.9857	3510781	596089
RG58	31.71684	-109.9717	3509510	597422
RG59	31.70714	-109.9625	3508443	598307
RG60	31.74326	-109.9478	3512461	599659
RG63	31.71890	-109.9500	3509758	599477
RG64	31.76100	-109.9305	3514443	601283
RG65	31.74468	-109.9310	3512633	601253

RG66	31.73361	-109.9228	3511414	602039.0
RG67	31.76388	-109.9173	3514774	602523
RG69	31.76996	-109.9026	3515463	603916
RG70	31.75860	-109.8988	3514207	604288
RG74	31.75776	-110.0438	3513984	590549
RG76	31.71952	-110.1279	3509679	582624
RG79	31.71426	-110.0867	3509127	586527
RG80	31.73302	-110.0418	3511243	590761
RG81	31.70568	-110.0574	3508200	589310
RG82	31.73618	-109.9427	3511680	600154
RG83	31.74377	-110.0530	3512426	589697
RG87	31.74636	-110.0142	3512745	593369
RG89	31.75681	-109.9830	3513931	596308
RG399	31.72487	-110.0528	3510331	589732

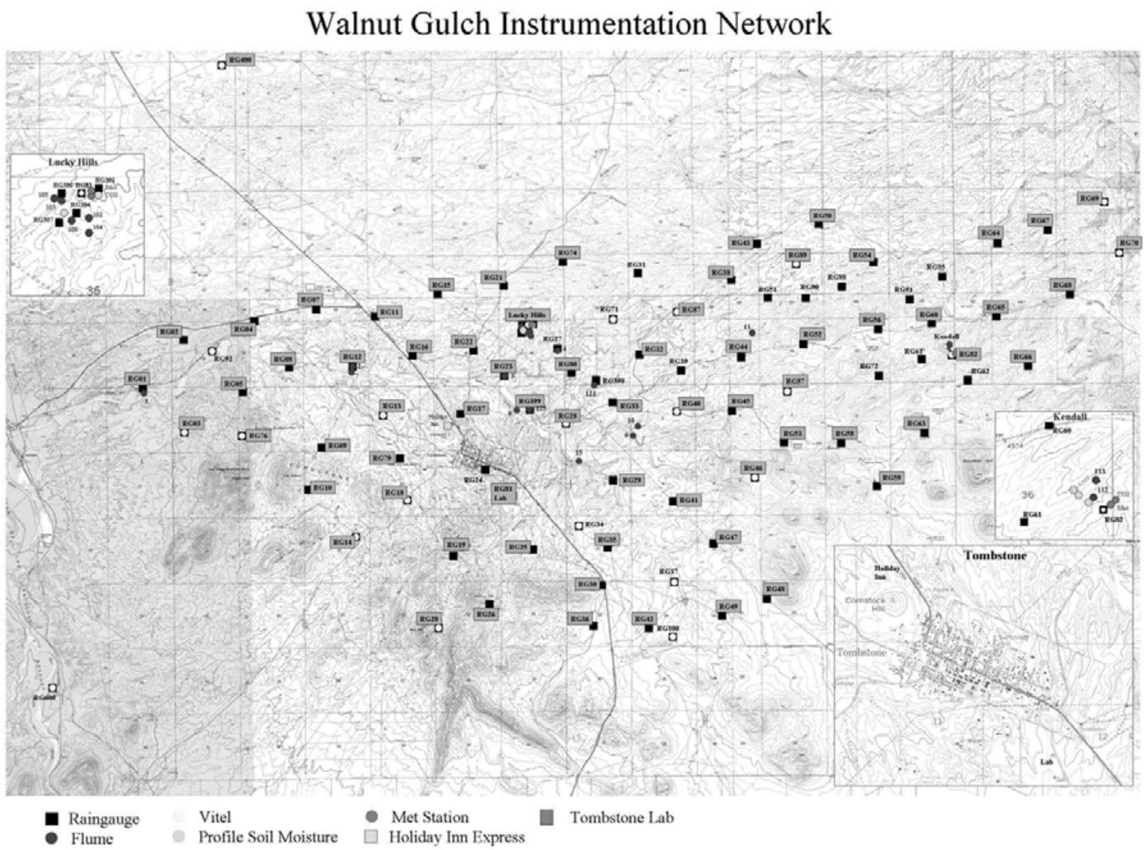


Figure 34. WG watershed sampling design.

5.2 Ground Sampling Sonora (SO)

Details on the sites that will be sampled in the SO region are under development. The road network and complexity of the terrain present significant obstacles to implementing the general sampling model described above. Regional sampling will include, as many of the network sites as possible and a topographic transect will be sampled on a daily basis. Intensive sampling along a transect of significant topographic relief and different ecosystems will take place within approximately 3 hours of a satellite overpass. The first sample will be taken around 10:00 am. The sampling will be done between 10:00 am and 4:00 pm. The topographic transect will begin near Odopepe and continue to permanent site 146. Figure 35 shows the current concept for sampling on a topographic-road network base map. The goal is to sample 40 or more sites.

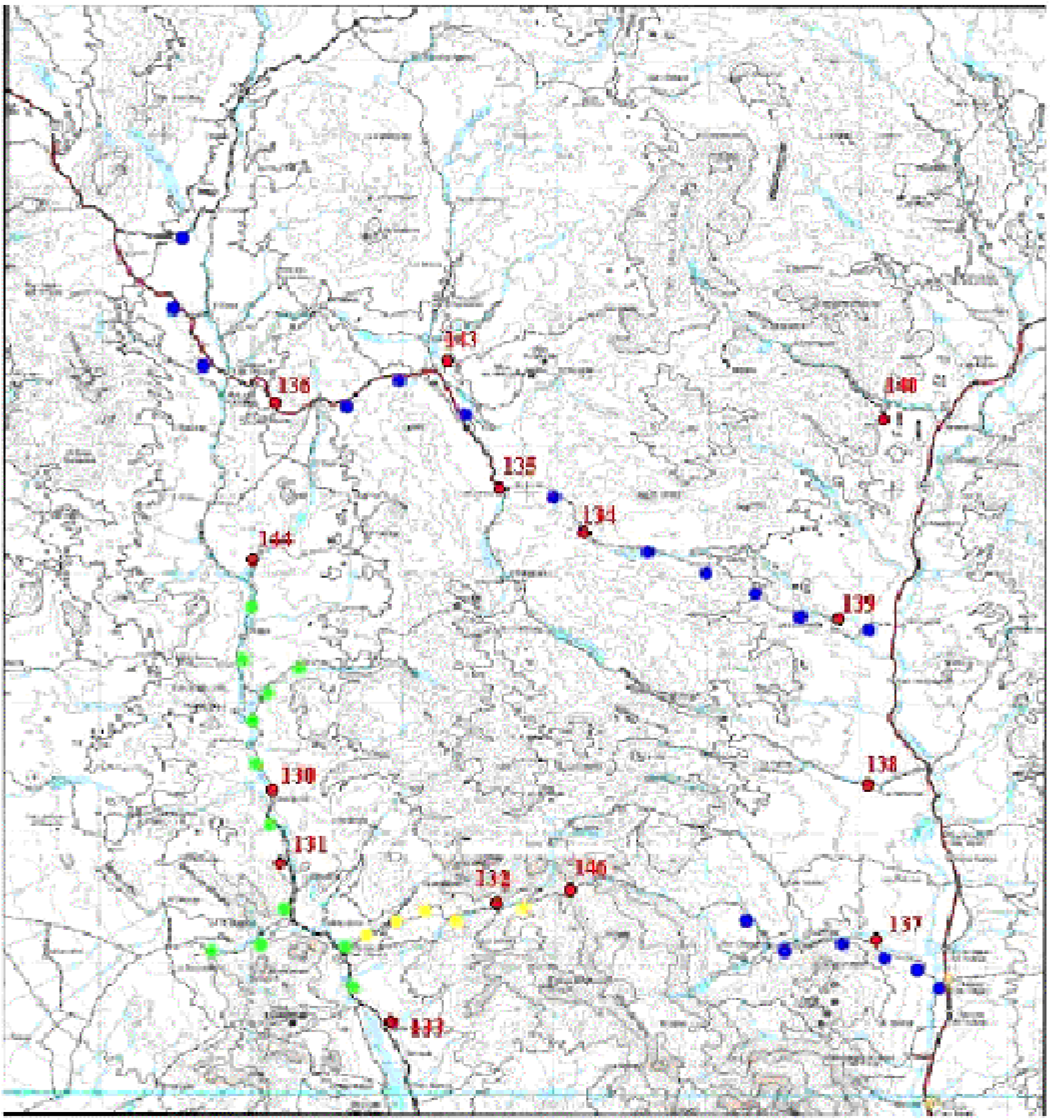


Figure 35. Topographic and road network map of the SO region. Green dots represent teams based in Opodepe, blue dots sites from Banamichi, yellow dots are on the topographic transect, and the red dots are permanent sites

6 VEGETATION SAMPLING FIELD CAMPAIGN

Vegetation water content (VWC, kg H2O/m2) or Equivalent Water Thickness (EWT, mm) can be estimated using wavelengths in the shortwave infrared (SWIR), such as on the MODerate resolution Imaging Spectroradiometer (MODIS) band 5 (1230-1250 nm) and band 6 (1628-1652 nm). However, these bands have a pixel size of 500 m, so validation of vegetation water content for a pixel is difficult. The Airborne Visible Infra-Red Imaging Spectrometer (AVIRIS) has 20 m pixels when flown on the ER-2 aircraft, which will be flown over the Arizona site in early August, and possibly over the Sonora site during SMEX04. We will test several algorithms for estimating VWC and EWT with the AVIRIS data. Ground measurements of VWC and EWT will be used to validate the AVIRIS algorithms. Then AVIRIS data will be used as validation of MODIS retrievals of VWC and EWT. These retrievals may depend on the angle of incidence of the MODIS coverage.

We will be sampling VWC and EWT for different plant communities for 28 sites in Arizona and 12 sites in Sonora covering a wide range of plant communities. We will measure stem and leaf water contents, leaf area index, plant cover, and leaf, soil and plot spectral reflectances. The significance of the proposed work is that with independent retrievals of VWC using MODIS data, soil moisture measurements from AMSR-E and HYDROS may be more accurate for the Sonora and Arizona study sites. The vegetation team is E. Raymond Hunt, Jr. (USDA ARS HRSL), Susan L. Ustin (University of California, Davis), Vern Vanderbilt (NASA Ames Research Center), Alfredo Huete (University of Arizona), René Lobato Sánchez (Laboratorio de hidrometeorologia, Instituto Mexicano de Tecnologiá del Agua), and Greg Asner (Carnegie Institute of Washington)

Vegetation water content (VWC) is the mass of liquid water per ground area (ie, kg/m2). For optical remote sensing, VWC is divided by the density of water for equivalent water thickness (EWT), which is the depth of liquid water for a given area. VWC of 1 kg/m2 is equal to an EWT of 1 mm. Canopy reflectance spectra from AVIRIS in the shortwave infrared (SWIR) will be used during SMEX04 to estimate the canopy EWT over the Arizona and Sonora study areas, which in turn will be used to validate potential MODIS data products.

Leaf EWT is the volume (mass/density) of liquid water divided by the one-sided leaf area. Most leaves have an EWT between 0.1 and 0.2 mm. EWT is convenient for scaling between leaf and canopy reflectances, because the EWT of the canopy is equal to the average leaf EWT of a leaf times the leaf area index (LAI).

Another measure of vegetation water content important for predicting wildfire spread is fuel moisture content (FMC), which is defined as the mass of liquid water per dry matter (kg/kg). To make the experimental data useful for a wide range of applications, the specific leaf area (SLA, m2/kg) defined as the one-sided leaf area per dry matter, or its reciprocal (specific leaf weight, SLW kg/m2), needs to be determined for the dominant vegetation types. FMC is equal to EWT * SLA. Furthermore, SLA is an important predictor of leaf reflectance in the near infrared, which when contrasted with leaf reflectance in the SWIR, is used to predict VWC with MODIS.

Thus, the basic set of measurements will be: (a) leaf EWT, (b) leaf reflectance, (c) leaf SLA, and (d) LAI. Woody stems also contain significant amounts of water that can be determined from microwave remote sensing; furthermore the amount of stem water will be related to vegetation type and LAI. Therefore, (e) shrub and tree density and (f) stem water content are important measurements. These variables are related to LAI, and will serve as another estimate for each plot. Finally, (g) ground cover, and (h) soil and canopy reflectances will be measured because these are important variables that affect MODIS data products.

The aircraft overflights are expected between August 2 and 12, 2004. Vegetation sampling will begin in AZ about July 28th. Sampling dates in SO are projected to be August 6-8.

6.1 Vegetation Communities and Sites

In both Arizona and Sonora, there are six primary vegetation communities:

Grasslands dominated by Bouteloua species (also has shrubs)
- i. B. eriopoda (black grama)
- ii. B. gracilis (blue grama)
- iii. B. curtipendula (sideoats grama)
- iv. Muhlenbergia porteri (bush muhly)
- v. Eragrostis lehmanniana (Lehmann lovegrass)

Riparian grasslands dominated by Sporobolus wrightii (sacaton)

Shrublands (few grasses, some herbaceous forbs)
- a. Larrea tridentata (creosote bush)
- b. Acacia constricta (white thorn acacia), A. greggii cats claw)
- c. Yucca elata, Y. schottii (yucca species)
- d. Olneya testosa (ironwood)
- e. Prosopis velutina (mesquite)

Riparian woodlands
- a. Populus fremontii (cottonwood)
- b. Prosopis velutina (mesquite)

Oak woodlands (lump various species)
- a. Quercus chrysolepis (canyon oak), Q. dunnii (Dunn oak)
- b. Q. emoryi (black oak), Q, oblongifolia (Mexican blue oak)
- c. Q. arizonica (Arizona oak), Q. rugosa (netleaf oak)
- d. Q. grisea (scrub oak), Q. hypoleucoides (silverleaf oak)
- e. Q. toumeyi (Toumey oak)
- f. Olneya testosa (ironwood)

Agriculture

In Arizona at least 26 sites will be sampled, most will be near soil moisture sampling locations. In Sonora, 12 sites will be sampled. The number of plots for each plant community is as follows.

Bouteloua grasslands	AZ 6	SO 4	
Riparian sacaton grasslands	AZ 2	SO none	
Shrublands	AZ 6	SO 4	
Riparian woodlands	AZ 6	SO 3	both mesquite and cottonwood
Oak woodlands	AZ 4	SO 3	use density differences on N and S slopes
Agriculture	AZ 2	SO none	

Four of the sites in AZ will be nearby the SMEX04 flux towers, Bouteloua grassland (Lucky Hills), a shrubland (Kendall), a riparian mesquite woodland (Lewis Springs), and a riparian sacaton grassland (Lewis Springs). These sites will be sampled on the day of the AVIRIS overflight.

6.2 Overall Protocol For Each Site

In Arizona, the plots will be located with GPS coordinates and flags before the intensive sampling around the date of the AVIRIS overflight. The plot dimensions will be 30 m by 30 m, which is 150% of the AVIRIS pixel size. Before dawn, the teams will drive to the selected study site so that in the twilight, canopy LAI can be measured with the LAI-2000. The following data will also be collected:

- shrub/tree height, density, diameters and water content
- tree/large shrub increment cores for age, sapwood thickness, and water content
- ground cover
- plot spectral measurements
- grass and forb plot clippings
- digital photographs with a fisheye lens for LAI
- leaves of the dominant species will be clipped and transported to the laboratory for detailed measurements.

7 OTHER ACTIVITIES

This section describes several complementary activities that will be conducted during the SMEX04 time frame that will be of benefit to soil moisture investigations.

7.1 Supplementary Raingage Network

In addition to operational meteorological networks in the U.S. and Mexico, the NAME project is funding several supplemental precipitation observing projects. For instance Figure 36 shows information on existing and supplemental raingages in Mexico (Shuttleworth Project).

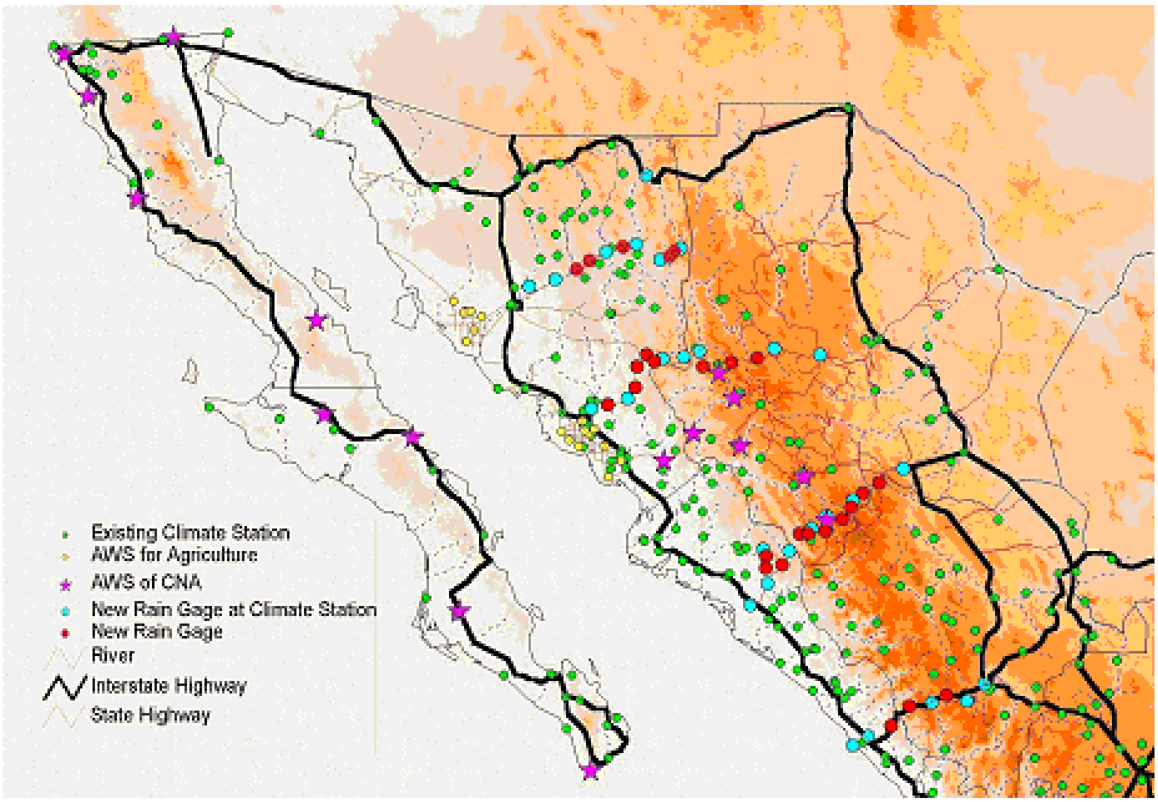


Figure 36. Existing and NAME supplemental climate, weather stations and raingages in the Hermosillo and Culiacan areas

7.2 Arizona Surface Flux Observations

The objective of this component of SMEX04 is to quantify energy, water and net carbon exchange from grassland, shrubland and riparian ecosystems during the experiment. Participants are Russ Scott, Bill Cable, and Bill Emmerich of the USDA-ARS Southwest Watershed Research Center, Tilden Meyers of NOAA/ARL Atmospheric Turbulence and Diffusion Division, Bill Kustas USDA-ARS Hydrology and Remote Sensing Lab and John Prueger USDA-ARS National Soil Tilth Lab.

Measurements

The surface energy balance, which includes measurements of net radiation, soil heat flux, sensible and latent heat flux will be made at multiple tower locations in Arizona. In addition, net carbon exchange will also be measured. Ancillary meteorological observations (air temperature, wind speed, vapor and atmospheric pressure, precipitation) will also be made at selected sites. Observations will commence in June and continue through the SMEX04 intensive observation period and for some period yet undetermined post experimental period.

Basic Tower Description

The flux towers consistent of a net radiometer instrument, and several soil heat flow transducers with soil temperature/moisture sensors for estimating the available energy. The sensible and latent heat fluxes are either measured by eddy covariance (EC) technique (consisting of a sonic anemometer and a fast response open path water vapor/CO2 sensor) or computed via gradients of air temperature, vapor pressure and CO2 concentrations (Bowen ratio-BR method). Measurements over the grassland and shrubland are made at 2-3 meters above local terrain. Measurements over riparian areas are 2-3 meters above the canopy.

Site descriptions and locations

The surface flux tower locations are listed in Table 25. Two of the flux observation sites are located within the Walnut Gulch Watershed. One site is a Shrub dominated sub-watershed (Lucky Hills: elevation 1372 m Figure 37) having a BR system that has been monitoring fluxes since 1996. In addition there is a long-term network of soil profile temperature and moisture measurement systems, rain gauge and runoff observations and a SCAN station. The other flux tower location is in a grass dominated sub-watershed (Kendall: elevation 1526 m Figure 38) also having a BR system in place since 1996 and similar set of soil temperature and moisture profile measurements, rain gauge and runoff observations. Both sites will also contain EC systems with 2 located in Kendall measuring at nominally 2 and 9 meters for investigating the effect of source area and riparian vegetation on flux observations. This will also provide an inter-comparison of flux estimation by EC and BR methods.

Three EC systems are in operation at sites in the upper San Pedro Basin along a mesquite invasion gradient from dense mesquite woodland to sacaton grassland. The dense woodland site (Charleston: Figure 39) has been operating since 2001. The mesquite shrubland site (Lewis Springs Mesquite: Figure 40) and the grassland site (Lewis Springs Sacaton: Figure 41) have been operating since mid-2002. Additionally there is an upland mesquite EC site at the Santa Rita Experimental Range near Green Valley, AZ (Figure 42), which has been operating since the beginning of 2004.

There is also an EC system in operation for the last several years near Elgin, AZ at the Audubon Research Ranch (Figure 43). The EC system is part of the AmeriFlux network. During the SMEX04 campaign, 3-4 EC towers will be erected within a 2 km radius of the existing tower for exploring spatial variability of fluxes within a similar ecosystem.

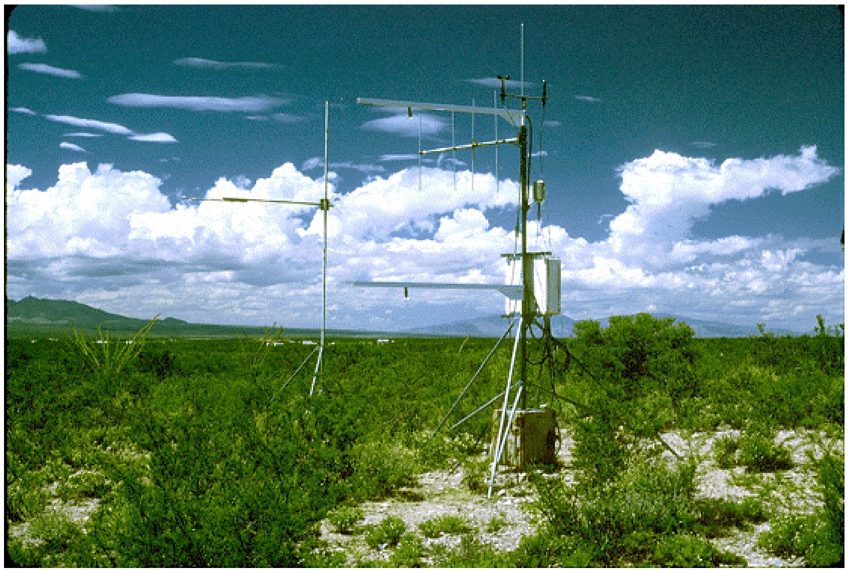


Figure 37. Lucky Hills surface flux tower.

Figure 38. Kendall surface flux tower.

Figure 39. Charleston surface flux tower site.

Figure 40. Lewis Springs Mesquite surface flux tower.

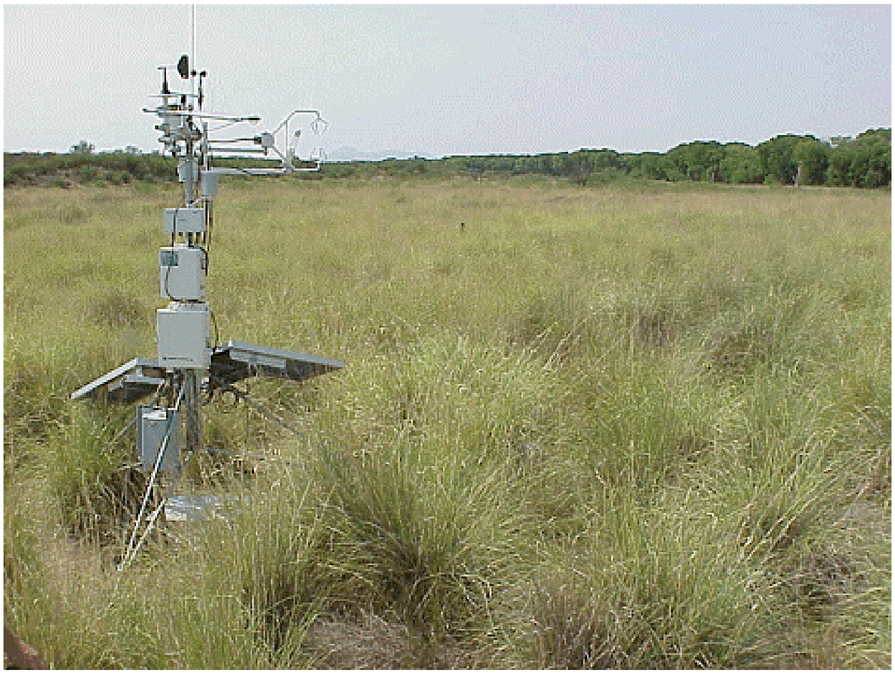


Figure 41. Lewis Springs Sacaton surface flux tower.

Figure 42. Santa Rita surface flux tower.

Figure 43. Audubon Research Ranch surface flux tower.

Table 25. Arizona Surface Flux Tower Locations

Site	Latitude (Degrees)	Longitude (Degrees)	Northing (m Zone 12)	Easting (m Zone 12)
Lucky Hills	31.74361	110.051	3512409	589889
Kendall	31.73611	109.941	3511674	600316
Charleston	31.66333	110.178	3503413	577926
Lewis Springs Mesquite	31.56583	110.134	3492638	582183
Lewis Springs Sacaton	31.56167	110.140	3492172	581617
Santa Rita	31.82139	110.866	3520646	512681
Audubon	31.59073	110.510	3495177	546488

7.3 Sonora Lower-Atmosphere Observations

This project, led by Ana Barros, consists of using installing and operating a pair of tethersonde stations to complement flux tower measurements across a vegetation contrast in the Sonora region during SMEX04. These measurements will allow us to monitor continuously the vertical structure of winds and thermodynamic state-variables in the lower 1-2 kms of the troposphere. These observations can be integrated with radiosonde observations planned for NAME in order to extend the profiles to the upper troposphere. Analysis of these data long with raingauge data and soils moisture data from SMEX will allow us to investigate the relationship between the diurnal cycle of winds and thermodynamics in the lower troposphere across a strong vegetation contrast both during wet periods (the NAM onset) and the ensuing mid-summer drought. These data should provide valuable information in understanding how land-atmosphere interactions impact upon the vertical stability of the atmosphere in the Sonora Mountains, and whether that has an impact on local recycling of rainfall. Furthermore, these observations will provide critical data to constrain the atmospheric corrections necessary in the processing and retrieval of microwave data to estimate soil moisture for SMEX04. A surface flux tower will be installed near the tethersonde location.

8 SAMPLING PROTOCOLS

This section describes various sampling protocols that have been used in previous experiments. It is anticipated that minor adjustments will be made to account for conditions in specific locales.

8.1 General Guidance on All Types of Sampling

- Sampling will be conducted **every day**. The sampling group leader on occasion may cancel if there is severe weather or a logistic issue arises.
- **Know your pace**. This helps greatly in locating sample points and gives you something to do while walking.
- If anyone questions your presence, politely answer identifying yourself as a scientist working on a NASA/USDA or IMADES soil moisture study with satellites. If you encounter any difficulties JUST LEAVE and report the problem to the group leader.
- Although gravimetric and vegetation sampling are destructive, try to **minimize your impact** by filling holes. Leave nothing behind.
- Please be considerate of the landowners and our hosts. **Don't** block roads, gates, and driveways. Keep sites, labs and work areas clean of trash and dirt.
- Watch your **driving speed**, especially when entering towns. Be courteous on dirt and gravel roads, lower speed=less dust.
- Avoid parking in tall grass; catalytic converters can be a **fire hazard**.
- **Close any gate** you open as soon as you pass.
- Some of the sampling sites may have livestock. Please be considerate towards the cattle and **do not try to scare them** away.
- Work in **teams of two. Carry a cell phone.**
- Keep your vehicle locked at all times.

8.2 Regional Site Surface Soil Moisture and Temperature

Regional sampling will take place within approximately 90 minutes of a satellite overpass. The first sample will be taken around 11:30 am. The sampling will be done between 11:30 am and 2:30pm.

Soil moisture and temperature sampling of the selected regions is intended to estimate the site average and standard deviation at the scale of passive microwave satellite footprints and grid cells. The variables that will be measured or characterized are:

- 0-6 cm soil moisture using the Theta Probe (TP) instrument
- 0-3 and 3-6 cm gravimetric soil moistures and bulk density using the scoop tool
- Surface temperature using a hand held infrared thermometer **(IF ASSIGNED)**
- 1 cm soil temperature
- 5 cm soil temperature
- 10 cm soil temperature
- GPS locations of all sample point locations (one time)

Preparation

- Arrive at the field headquarters at assigned time. Check in with group leader and review notice board.
- Assemble sampling kit
    - Bucket
    - Theta Probe (TP) and data logger (use the same probe each day)
    - Scoop tool
    - Soil Moisture Insertion Tool (SMITY)
    - 10 cm spatula
    - 4 cm spatula
    - Funnel
    - Bottle brush
    - Notebook
    - Pens
    - Box of cans (see note below)
    - Soil thermometer
    - Handheld infrared thermometer (IF ASSIGNED)
    - Extra batteries
    - Screwdriver
    - Camera (WHEN ASSIGNED)
    - First aid kit (per car)
    - Cell Phone

- Verify that your TP, data logger, infrared instrument, and soil thermometer are working.
- For the regional sites, each team should take one box of 18 cans. The cans will be numbered XX01-XX18.
- The first time you sample, it will help to use paint to mark the field entry point and sample point location.
- All sample points should be located with a GPS once during the experiment. Points will be referenced by Site.
- Check weather daily and watch for flashflooding

Procedure

- Upon arrival at a site, note site id, your name(s), TP ID, and time in notebook. Draw a schematic of the field (It might be a good idea to do this before you go out for the day).
- Assemble 2 sequential cans. ***Odd numbered cans are used for the 0 – 3 cm sample and even numbered cans are used for the 3 – 6 cm sample.***
- Go to the pre-established sampling location.
    - The sampling sites should be at least 100 m inside the field boundaries away from any roadways. On subsequent days, sample an adjacent undisturbed location.
    - Sample in the row adjacent to the row you are working in, it is suggested that this be the row to your right (If there are no rows choose a random location within 1 meter of the selected location).

- Using the scoop tool to collect one gravimetric soil moisture sample for 0-3 cm and 3-6 cm following the Scoop Tool Sampling protocol, enter can numbers in book. This sample should be done coincident with the third TP sample, in either row crop or non-row crop fields.
- Take five Theta Probe readings within a 1 m^2 area. Record the VSM reading in the book.
- One soil temperature (Degrees C) for 1 cm, 5 cm and 10 cm using the probe, enter values in book
- At all Apogee sites, one averaged surface thermal infrared temperature (Degrees C) using infrared thermometer, enter value in book. All teams may not collect this.
- Record your stop time and place cans in box. Try to keep them cool.

Sample Data Processing

- Return to the field headquarters immediately upon finishing sampling.
- Weigh the gravimetric samples and record on the data sheets that will be provided. Use a separate sheet for each date and record cans sequentially. (see Figure 44)
- Transfer temperature and other requested data to data sheets (same sheet used for GSM).
- Place cans in oven and data sheet in collection box.
- Clean your other equipment.

SMEX04
Soil Moisture Sampling Data Sheet

Dates: ____________ Team: ____________
Time: ____________ Observers: ____________

Site ID	Local Sample Time	IRT in C	Soil Temp in C			Theta Probe (%)					0-3 cm			3-6 cm		
			1 cm	5 cm	10cm	A	B	C GSM	D	E	Can ID	Wet Wgt	Dry Wgt	Can ID	Wet Wgt	Dry Wgt

Figure 44. Example of the gravimetric soil moisture sampling data sheet.

8.3 Watershed Site Surface Soil Moisture and Temperature

Watershed sampling will take place within approximately 2 hours of a satellite overpass. The first sample will be taken around 11:00 am. The sampling will be done between 11:00 am and 3:00pm.

Soil moisture and temperature sampling of the selected regions is intended to estimate the site average and standard deviation at the scale of passive microwave satellite footprints and grid cells. The variables that will be measured or characterized are:

- 0-6 cm soil moisture using the Theta Probe (TP) instrument
- 0-3 and 3-6 cm gravimetric soil moistures and bulk density using the scoop tool (IF ASSIGNED)
- Surface temperature using a hand held infrared thermometer (IF ASSIGNED)

- 1 cm soil temperature
- 5 cm soil temperature
- 10 cm soil temperature
- GPS locations of all sample point locations (one time)

Preparation

- Arrive at the field headquarters at assigned time. Check in with group leader and review notice board.
- Assemble sampling kit
    - Bucket
    - Theta Probe and data logger (use the same probe each day, it will have an ID)
    - Scoop tool (IF ASSIGNED)
    - Soil Moisture Insertion Tool (SMITY)
    - 10 cm spatula
    - 4 cm spatula
    - Funnel
    - Bottle brush
    - Notebook
    - Pens
    - Box of cans (see note below)
    - Soil thermometer
    - Handheld infrared thermometer (IF ASSIGNED)
    - Extra batteries
    - Screwdriver
    - Camera (WHEN ASSIGNED)
    - First aid kit (per car)
    - Cell Phone

- Verify that your TP, data logger, infrared instrument, and soil thermometer are working.
- For the regional sites, each team should take the appropriate number of cans. The cans will be numbered XX01-XX18.
- The first time you sample, it will help to use paint to mark the field entry point and sample point location.
- All sample points should be located with a GPS once during the experiment. Points will be referenced by Site.
- Check weather daily and watch for flash flooding.

Procedure

- Upon arrival at a site, note site id, your name(s), TP ID, and time in notebook. Draw a schematic of the field (It might be a good idea to do this before you go out for the day).
- Assemble 2 sequential cans. ***Odd numbered cans are used for the 0 – 3 cm sample and even numbered cans are used for the 3 – 6 cm sample.*** (IF ASSIGNED)
- Go to the pre-established sampling location.

- The sampling sites should be within 10 m of the raingages, which are associated with the watershed sampling site. Efforts should be made to make the sampling location representative of the surrounding area.
- (IF ASSIGNED) Using the scoop tool to collect one gravimetric soil moisture sample for 0-3 cm and 3-6 cm following the Scoop Tool Sampling protocol, enter can numbers in book. This sample should be done coincident with the third TP sample, in either row crop or non-row crop fields.
- Take five (5) Theta Probe readings within a 1 m^2 area. Record the VSM reading in the book. On subsequent days, sample adjacent 1 m^2 areas.
- One soil temperature (Degrees C) for 1 cm, 5 cm and 10 cm using the probe near the third TP sampling point, enter values in book
- At all Apogee sites, one averaged surface thermal infrared temperature (Degrees C) using infrared thermometer, enter value in book. All teams may not collect this.
- Record your stop time and place cans in box. Try to keep them cool.

Sample Data Processing

- Return to the field headquarters immediately upon finishing sampling.
- Weigh the gravimetric samples and record on the data sheets that will be provided. Use a separate sheet for each date and record cans sequentially. (see Figure 44)
- Transfer temperature and other requested data to data sheets (same sheet used for GSM).
- Place cans in oven and data sheet in collection box.
- Clean your other equipment.

8.4 Topographic Transect Sampling

To complement the regional sampling in the Sonora region, a topographic transect will be sampled on a daily basis. Intensive sampling along a transect of significant topographic relief and different ecosystems will take place within approximately 3 hours of a satellite overpass. The first sample will be taken around 10:00 am. The sampling will be done between 10:00 am and 4:00 pm.

Soil moisture and temperature sampling of the areas along the topographic transect is intended to estimate the transect mean, variability and trend, and its relation to underlying landscape features. The variables that will be measured or characterized are:

- 0-6 cm soil moisture using the Theta Probe (TP) instrument
- 0-3 and 3-6 cm gravimetric soil moistures and bulk density using the scoop tool.
- Surface temperature using a hand held infrared thermometer
- 1 cm soil temperature
- 5 cm soil temperature
- 10 cm soil temperature (if possible)
- Photograph and site characteristics of all sample points (one time)
- GPS locations of all sample point locations (one time)

Preparation

Arrive at the field headquarters at assigned time. Check in with group leader and review notice board. Assemble sampling kit, including:

- Bucket
- Theta Probe and data logger (use the same probe each day, it will have an ID)
- Scoop tool
- Soil Moisture Insertion Tool (SMITY)
- 10 cm spatula
- 4 cm spatula
- Funnel
- Bottle brush
- Notebook
- Pens
- Box of cans (see note below)
- Soil thermometer
- Handheld infrared thermometer
- Extra AA batteries
- Screwdriver
- Camera
- First aid kit (per car)
- Cell Phone (if available, if coverage)

Verify that your TP, data logger, infrared instrument, and soil thermometer are working.
For the transect sites, the teams should take the appropriate number of cans. The cans will be numbered XX01-XX18, where XX is the day, from A to ZZ.

The first days of the field campaign, site selection will be performed so that each location along the transect is properly identified, the GPS coordinates recorded as way points and the area prepared for sampling during the campaign. A path to the sample site will be determined so that no sampling traffic affects sampling area. Paint or flagging will be used to mark the site and path.

All sample points should be located with a GPS once during the experiment. Points will be referenced by Site, numbered from 1 to N, where N is the total number of sites along transect (anticipated to be 15-25).

Check weather daily and watch for flash flooding (if available).

Procedure

- Upon arrival at a site, note site id, your name(s), TP ID, and time in notebook. Draw a schematic of the field (It might be a good idea to do this before you go out for the day).
- Assemble 2 sequential cans. Odd numbered cans are used for the 0 – 3 cm sample and even numbered cans are used for the 3 – 6 cm sample.

- Go to the pre-established sampling location.
- The sampling sites should be within 5 m of the pre-established locations. One of sites (possibly two) will be associated with a continuous soil moisture and rain gauge recorders. For these sites, the sampling should be performed within 10 meters of the installation. In every case, efforts should be made to make the sampling location representative of the surrounding area.
- Use the scoop tool to collect one gravimetric soil moisture sample for 0-3 cm and 3-6 cm following the Scoop Tool Sampling protocol, enter can numbers in book.
- Take five (5) Theta Probe readings within a 1 m^2 area. Record the VSM reading in the book. On subsequent days, sample adjacent 1 m^2 areas.
- Take one soil temperature (Degrees C) for 1 cm, 5 cm and 10 cm (if possible) using the probe near the third TP sampling point, enter values in book.
- Record your stop time and place cans in box. Try to keep them cool.

Sample Data Processing

- Return to the field headquarters immediately upon finishing sampling.
- Weigh the gravimetric samples and record on the data sheets that will be provided. Use a separate sheet for each date and record cans sequentially. (see Figure 44)
- Transfer temperature and other requested data to data sheets.
- If oven is available, place cans in oven and data sheet in collection box. Otherwise, store soil sample in sealed plastic bag for future laboratory analysis.
- Clean your other equipment.

8.5 Site Characterization

One team will be assigned to general site characterization, including estimation of surface roughness, bulk density, Leaf Area Index (LAI), and spectral radiance measurements. Approximately 2-3 sites will be characterized per day. Each site will be sampled at least once during the experiment and if time permits, multiple measurements of LAI and spectral radiance will be made. Non-destructive sampling of LAI using LiCor LAI-2000 instruments will be conducted. Surface reflectance measurements will be made at as many sites as possible using a CROPSCAN instrument. If necessary, vegetation sampling will be coordinated with the site characterization team. Vegetation sampling will be conducted on a subset of the soil moisture sites and will vary by region. Three representative locations within each selected field will be sampled during the course of the study to quantify the full range of vegetative cover

8.6 Theta Probe Soil Moisture Sampling and Processing

There are two types of TP configurations; Type 1 (Rod) (Figure 45) and Type 2 (Handheld) (Figure 46). They are identical except that Type 1 is permanently attached to the extension rod. Each unit consists of the probe (ML2x) and the data logger or moisture meter (HH2). The HH2 reads and stores measurements taken with the ThetaProbe (TP) ML2x soil moisture sensors. It can provide milliVolt readings (mV), soil water (m3.m-3), and other measurements. Readings are saved with the time and date of the reading for later collection via a PC.

The HH2 is shown in Figure 47. It applies power to the TP and measures the output signal voltage returned. This can be displayed directly, in mV, or converted into other units. It can convert the mV reading into soil moisture units using conversion tables and soil-specific parameters. Tables are installed for Organic and Mineral soils, however, greater accuracy is possible by developing site-specific parameters. For SMEX04, all observations will be recorded as VSM and mV using the Mineral setting.

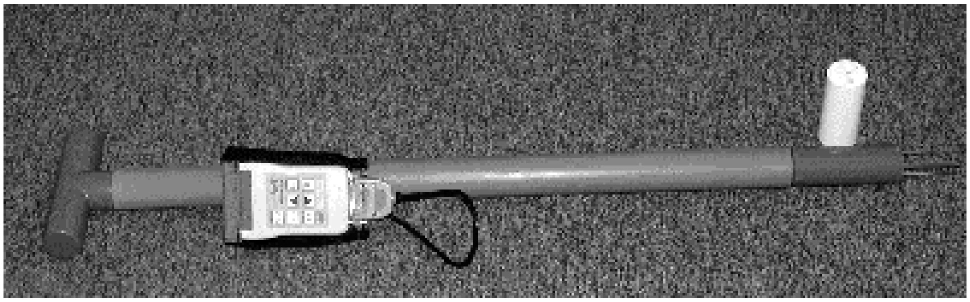


Figure 45. Theta Probe Type 1 (with extension rod).

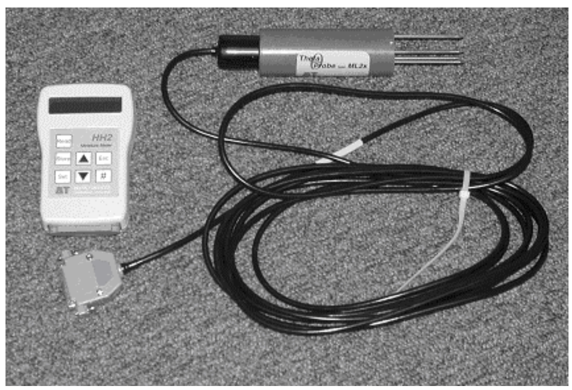


Figure 46. Theta Probe Type 2.

Figure 47. HH2 display.

Occasionally, the soil is too hard to successfully insert a TP; therefore, a jig (Soil Moisture Insertion Tool – SMITY) has been constructed, shown in Figure 48. This is a tool used to make holes in hard or difficult soils to ease the stress on the TP. To use, place the slider plate (Figure 49) on the surface to be probed. Using pressure or a hammer, drive the SMITY into the ground. Avoid any side-to-side movement, to avoid faulty measurements. Once the SMITY is completely in the ground, hold the slider plate on the surface and pull straight up on the SMITY. Holding the slider plate to the ground should maintain the surface for proper TP insertion. Clean the SMITY and proceed with the TP measurement. Insert the TP probe exactly into the holes created by the SMITY. The TP tines are slightly larger than the holes, but will be much easier to insert than without the SMITY.

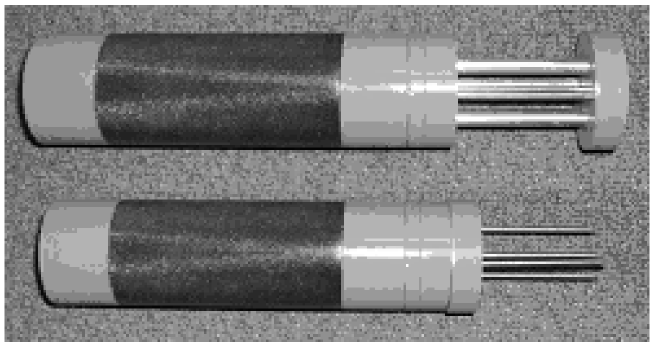


Figure 48: SMITY, Soil Moisture Insertion Tool, with slider extended and retracted.

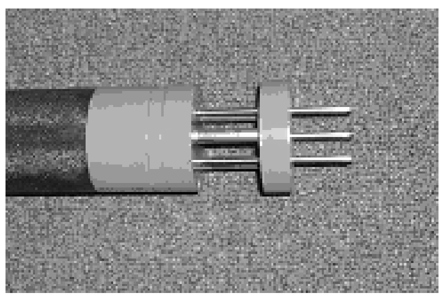


Figure 49: Close-up of the SMITY slider.

Use of the TP is very simple - you just push the probe into the soil until the rods are fully covered, then using the HH2 obtain a reading. Some general items on using the probe are:

- One person will be the TP coordinator. If you have problems see that person.
- A copy of the manual for the TP and the HH2 will be available at the field HQ. They are also available online as pdf files at http://www.dynamax.com/#6, http://www.delta-t.co.uk and http://www.mluri.sari.ac.uk/thetaprobe/tprobe.pdf.
- Each TP will have an ID, use the same TP in the same sites each day.
- The measurement is made in the region of the four rods.
- Rods should be straight.
- Rods can be replaced.
- Rods should be clean.
- Be careful of stones or objects that may bend the rods.

- Some types of soils can get very hard as they dry. If you encounter a great deal of resistance, use the SMITY or stop using the TP in these fields. Supplemental GSM sampling will be used.
- Check that the date and time are correct and that Plot and Sample numbers have been reset from the previous day.
- Disconnect sensor if you see the low battery warning message.
- Protect the HH2 from heavy rain or immersion.
- The TP is sensitive to the water content of the soil sample held within its array of 4 stainless steel rods, but this sensitivity is biased towards the central rod and falls off towards the outside of this cylindrical sampling volume. The presence of air pockets around the rods, particularly around the central rod, will reduce the value of soil moisture content measured.
- Do not remove the TP from soil by pulling on the cable.
- Do not attempt to straighten the measurement rods while they are still attached to the probe body. Even a small degree of bending in the rods (>1mm out of parallel), although not enough to affect the inherent TP accuracy, will increase the likelihood of air pockets around the rods during insertion, and so should be avoided. See the TP coordinator for replacement.

Before Taking Readings for the Day Check and configure the HH2 settings

1. Press **Esc** to wake the *HH2.*

<u>*Check Battery Status*</u>

2. Press **Set** to display the **Options** menu
3. Scroll down to **Status using** the **up** and **down** keys and press **Set.**
4. The display will show the following
   Mem %   Batt %
   Readings #.
   - If Mem is not 0% see the TP coordinator.
   - If Battery is less than 50% see TP coordinator for replacement. The HH2 can take approximately: 6500 TP readings before needing to replace the battery.
   - If Readings is not 0 see the TP coordinator
5. Press **Esc** to return to the start-up screen**.**

<u>*Check Date and Time*</u>

6. Press **Set** to display the **Options** menu
7. Scroll down to **Date and Time using** the **up** and **down** keys and press **Set.**
8. Scroll down to **Date** using the up and down keys and press **Set** to view. It should be in DD/MM/YY format. If incorrect see the TP coordinator or manual.
9. Press **Esc** to return to the start-up screen**.**
10. Press **Set** to display the **Options** menu
11. Scroll down to **Date and Time using** the **up** and **down** keys and press **Set.**
12. Scroll down to **Time** using the up and down keys and press **Set** to view. It should be local (24 hour) time. If incorrect see the TP coordinator or manual.
13. Press **Esc** to return to the start-up screen**.**

<u>*Set First Plot and Sample ID*</u>

14. Press **Set** at the start up screen to display the **Options** Menu**.**
15. Scroll down to **Data** using the **up** and **down** keys and press **Set.**
16. Select **Plot ID** and press **Set** to display the **Plot ID** options.

17. The default ID should be A. If incorrect scroll through the options, from A to Z, using the **up** and **down** keys, and press **Set** to select one.
18. Press **Esc** to return to the main Options menu**.**
19. Scroll down to **Data** using the **up** and **down** keys and press **Set**
20. Scroll down to **Sample** and press **Set** to display available options. A sample number is automatically assigned to each reading. It automatically increments by one for each readings stored. You may change the sample number. This can be any number between 1 and 2000.
21. The default ID should be 1. If incorrect scroll through the options, using the **up** and **down** keys, and press **Set** to select one.
22. Press **Esc** to return to the main Options menu.

Select Device ID

23. Each HH2 will have a unique ID between 0 and 255. Press **Set** at the start up or readings screen to display the main **Options** menu**.**
24. Scroll down to **Data** using the **up** and **down** keys and press **Set.**
25. Select **Device ID** and press **Set** to display the **Device ID** dialog.
26. Your ID will be on the HH2 battery cover.
27. Scroll through the options, from 0 to 255, and press **Set** to select one.
28. Press **Esc** to return to the main menu.

To take Readings

7 Press **Esc** to wake the *HH2.*

8 Press **Read**

If successful the meter displays the reading, e.g.-

ML2 Store?
32.2%vol

9 Press **Store** to save the reading.

The display still shows the measured value as follows:

ML2
32.2%vol

Press **Esc** if you do not want to save the reading. It will still show on the display but has not been saved.

ML2
32.2%vol

10 Press **Read** to take the next reading or change the optional meter settings first. such as the Plot ID. Version 1 of the Moisture Meter can store up to 863 if two sets of units are selected.

Troubleshooting

Changing the Battery

- *The HH2 unit works from a single **9 V PP3** type battery. When the battery reaches 6.6V, (~25%) the HH2 displays :*

  ***Please Change**
  Battery

- On receiving the above warning have your data uploaded to the PC next, or replace the battery. Observe the following warnings:

- ***WARNING 1: Disconnect the TP, immediately on receiving this low battery warning. Failure to heed this warning could result in loss of data.***
- ***WARNING 2: Allow HH2 to sleep before changing battery.***
- ***WARNING 3: Once the battery is disconnected you have 30 seconds to replace it before all stored readings are lost.*** If you do not like this prospect, be reassured that your readings are safe indefinitely, (provided that you do disconnect your sensor and you do not disconnect your battery). The meter will, when starting up after a battery change always check the state of its memory and will attempt to recover any readings held. So even if the meter has been without power for more than 30 seconds, the meter may still be able to retain any readings stored.

Display is Blank

- The meter will sleep when not used for more than 30 seconds. This means the display will go blank.
- First check that the meter is not sleeping by pressing the Esc key. The display should become visible instantly.
- If the display remains blank, then try all the keys in case one key is faulty.
- Try replacing the battery.
- If you are in bright light, then the display may be obscured by the light shining on the display. Try to move to a darker area or shade the display.

Incorrect Readings being obtained

- Check the device *is connected to the meter correctly.*
- Has the meter been set up with the correct device.

Zero Readings being obtained

- If the soil moisture value is always reading zero, then an additional test to those in the previous section is to check the battery.

Settings Corrupt Error Message

- *The configurations such as sensor type, soil parameters, etc. have been found to be corrupt and are lost. This could be caused by electrical interference, ionizing radiation, a low battery or a software error.*

Memory Failure Error Message

- The unit has failed a self-test when powering itself on. The Unit's memory has failed a self test, and is faulty. Stop using and return to HQ.

Some Readings Corrupt Error Message

- Some of the stored readings in memory have been found to be corrupt and are lost. Stop using and return to HQ.

Known Problems

- When setting the date and time, an error occurs if the user fails to respond to the time and date dialog within the period the unit takes to return to itself off. (The solution is to always respond before the unit times out and returns to sleep).
- The Unit takes a reading but fails to allow the user to store it. (This can be caused if due to electrical noise, or if calibrations or configurations have become corrupted. An error message will have been displayed at the point this occurred.

8.7 Gravimetric Soil Moisture Sampling with the Scoop Tool

- Remove vegetation and litter.
- Use the large spatula (6 cm) to cut a vertical face at least 6 cm deep (Figure 50a).
- Push the GSM tool into this vertical face. The top of the scoop should be parallel with the soil surface. (Figure 50b).
- Use the large spatula to cut a vertical face on the front edge of the scoop (Figure 50c).
- Use the small spatula to cut the sample into a 0-3 and a 3-6 cm depth sample.
- Place each sample depth in a separate can, the small spatula aids extraction (Figure 50d). Remember that the odd numbered cans are for the top layer and the even are for the deeper layer (remember to use cans sequentially and odd numbers for the 0-3 and even for 3-6 cm samples).
- Record these can numbers in the field notebooks at the point location on the map.
- At the specific sampling points where it is required, measure the soil temperature at 1, 5 and 10 cm depths using the digital thermometer provided. Record these values in degrees C to one decimal point in the field notebooks at the point location on the map.
- At the specific sampling points where it is required, measure the surface temperature. Record these values in degrees C to one decimal point in the field notebooks at the point location on the map.

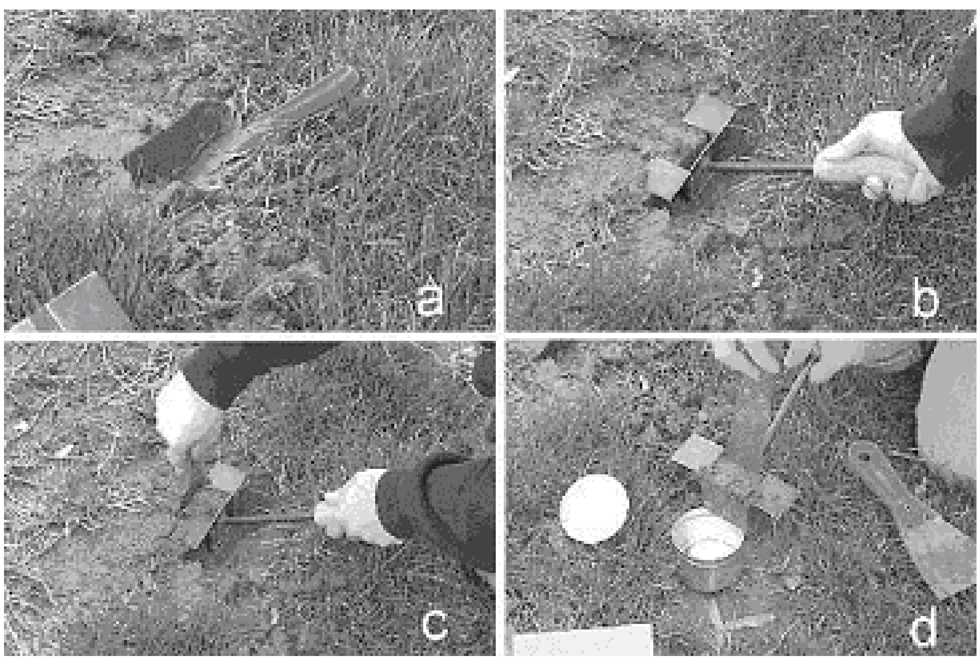


Figure 50. How to take a gravimetric soil moisture sample.

8.8 Gravimetric Soil Moisture and Bulk Density Sampling with the Coring Tool (IF ASSIGNED)

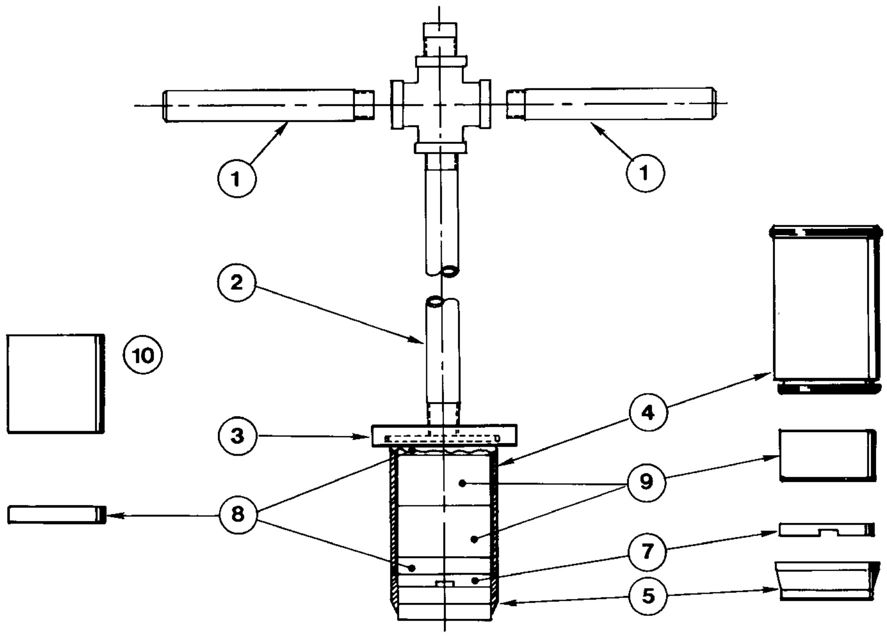
- The tool is called a 200-A soil core sampler.
- Figure 51 shows the parts of the apparatus.
- This can be replaced using a spanner tool to unscrew it from the barrel.
- The cap is unscrewed to insert or remove rings.
- The ring volumes are 3 cm=>68.7 cm^3. (diameter of the ring is 5.4 cm)

Procedure for Taking a Sample

- Insert five sample rings and the extractor ring in the following order starting from the cutting end
    - Extractor
    - 1 cm
    - 1 cm
    - 3 cm
    - 3 cm
- Replace cap with handle
- Insert the coring tool into the soil. If necessary, the hammer tool can be used. The hammer rod is inserted into the handle.
- Stop when the lip of the cap reaches the surface, try not to compact the sample.
- Remove the core and inspect the tip to make sure the notches on the extractor ring are clear. Use the extractor tool (Figure 51) to assist in cleaning these notches. Also inspect for separation within the coring tool by looking for protruding soil at the bottom of the tool. If there is separation, dispose of this sample and start again.
- Remove the cap.
- Use the extractor tool (from the bottom or cutting edge) to push the rings out the top or cap end.
- Using a wide spatula, cut the rings apart into the soil moisture cans using the soil funnel to insure capture of the entire sample..
- Place the 0-3 cm and 3-6 cm samples in cans (Remember odd-0-3 cm and even-3-6 cm).
- It can be difficult to extract a perfect surface 3 cm sample for bulk density. However, it s still useful as a GSM sample. Please make a note on the sample quality in your notebook.
- Clean all rings.

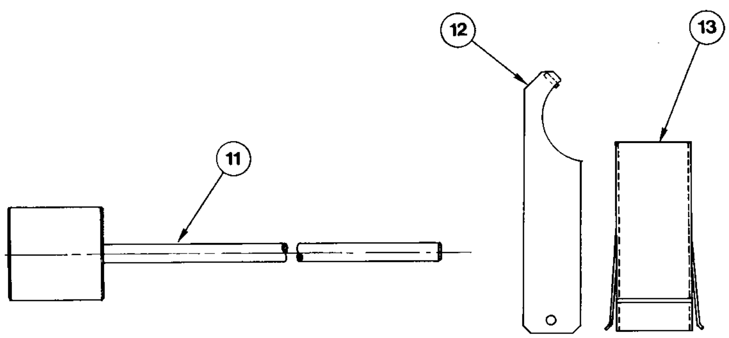
Computing the Volumetric Soil Moisture and Bulk Density

- Compute the sample GSM and dry mass
- Divide the mass of the soil by the volume of the cylinder (3 cm) hole to obtain the sample bulk density
- Compute VSM=GSM*BD



PARTS BREAKDOWN

ITEM NO.	PART NO.	DESCRIPTION	ITEM NO.	PART NO.	DESCRIPTION
1	201-6	HANDLE			
2	201-100	STEM ASSEMBLY	7	201-9	NOTCHED EXTRACTOR RING
3	201-4	CAP	8	208	CYLINDER 1 CM. LONG
4	201-3	BARREL	9	207	CYLINDER 3 CM. LONG
5	201-1	BLADE CORING TIP	10	206	CYLINDER 6 CM. LONG



PARTS BREAKDOWN (CONTINUED)

ITEM NO.	PART NO.	DESCRIPTION
11	202	DRIVE HAMMER
12	203	SPANNER WRENCH
13	204	SLOTTED CORE EXTRACTOR

Figure 51. Coring tool parts.

8.9 Gravimetric Soil Moisture Sample Processing

All GSM samples are processed to obtain a wet and dry weight. It is the sampling teams responsibility to deliver the can, fill out a sample set sheet, and record a wet weight at the field headquarters. A lab team will place the samples in the drying ovens. They will perform the removal of samples from the oven, dry weighing, and can cleaning.

All gravimetric soil moisture (GSM) samples taken on one day will be collected from the field headquarters in late afternoon or early the following morning. These samples will remain in the ovens until the morning of the second day (approximately 24 hours).

Wet Weight Procedure

1. Turn on balance.
2. Tare.
3. Obtain wet weight to two decimal places and record on sheet.
4. Process your samples in sample numeric order.
5. Place the CLOSED cans back in the box. Arrange them sequentially.
6. Place box and sheet in assigned locations.

Dry Weight Procedure

1. Each day obtain a balance reference weight on the wet weight balance and the dry weight balance.
2. Pick up all samples from field headquarters.
3. Turn off oven and remove samples for a single data sheet and place on tray.
4. These samples will be hot. Wear the gloves provided
5. Turn on balance.
6. Tare.
7. Obtain dry weight to two decimal places and record on sheet.
8. Process your samples in sample numeric order.
9. All samples should remain in the oven for approximately 20-22 hours at 105^{o}C.
10. Try to remove samples in the order they were put in.
11. Load new samples into oven.
12. Turn oven on.
13. Clean all cans that were removed from the ovens and place empty cans in boxes. Check that can numbers are readable and replace any damaged or lost cans with spares.
14. Return the clean cans to the field HQ before 8:00 am the following day.

Data Processing

1. Enter all data from the sheets into an Excel spreadsheet. One file per day, one worksheet per site.
2. There will be a summary file for each day that will contain the means and standard deviations.

3. All files are backed up with a floppy disk copy.
4. The summary file will be transmitted to a central collection point on a daily basis.
5. You may keep copies of raw data for any site that you actually sample at this stage. You may not take any other data until quality control has been conducted

8.10 Soil Temperature Probes

Several different types of temperature probes may be used to measure soil temperature. These all have a metal rod, plastic top and digital readout. The version used will be the Max/Min Waterproof Digital Thermometer (Figure 51).

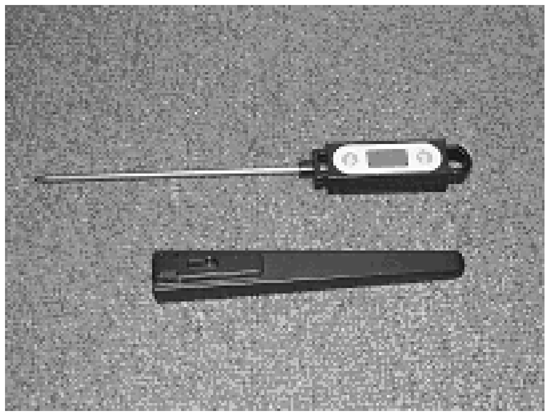


Figure 51. Temperature Probe with Handle/Cover

To Operate:

1. Press On/Off to switch on
2. Verify that the measurement is in Celsius and that the probe is not set to Max or Min
3. Probed into 1 cm of soil at the desired location.
4. Wait for reading to stabilize, and then record the number in the field book.
5. Push the probe to a depth of 5 cm, let it stabilize and record data.
6. Push Probe to a depth of 10 cm, let it stabilize and record data.
7. Turn off probe and cover.

If necessary the cover can be placed on the top of the probe and used as a handle, but do not force the probe into the ground with undue force, as the probe may break.

Normal operation of the probe is simple, but please make sure that neither Max nor Min appear on the LCD. This is a different mode of operation and will not be used for this experiment.

8.11 Soil Bulk Density

All regional sites involved in gravimetric soil moisture sampling will be characterized for soil bulk density and surface roughness. The bulk density method being used is a volume extraction technique that has been employed in most of the previous experiments and is especially appropriate for the surface layer. Three replications are made for each regional site.

The Bulk Density Apparatus -

The Bulk Density Apparatus itself consists of a 12" diameter plexiglass piece with a 5" diameter hole in the center and three 3/4" holes around the perimeter. Foam is attached to the bottom of the plexiglass. The foam is 2 inches high and 1 1/2 inches thick. The foam is attached so that it follows the circle of the plexiglass.

Other Materials Required for Operation:

- Three 12" (or longer) threaded dowel rods and nuts are used to secure the apparatus to the ground.
- A hammer or mallet is used to drive the securing rods into the ground.
- A bubble level is used to insure the surface of the apparatus is horizontal to the ground.
- A trowel is used to break up the soil and to remove the soil from the hole.
- Oven-safe bags are used to hold the soil as it is removed from the ground. The soil is left in the bag when it is dried in the oven.
- Water is used to determine the volume of the hole.
- A plastic jug is used to carry the water to the site.
- One-gallon plastic storage bags are used as liners for the hole and to hold the water.
- A 1000 ml graduated cylinder is used to determine the volume of the water. Plastic is best because glass can be easily broken in the field.
- A hook-gauge is used to insure water fills the apparatus to the same level each time.

Selecting and Preparing an Appropriate Site -

1. Select a site. An ideal site to conduct a bulk density experiment is: relatively flat, does not include any large (>2 cm) rocks or roots in the actual area that will be tested and has soil that has not been disturbed.
2. Ready the site for the test. Remove all vegetation, large (>2 cm) rocks and other debris from the surface prior to beginning the test. Remove little or no soil when removing the debris.

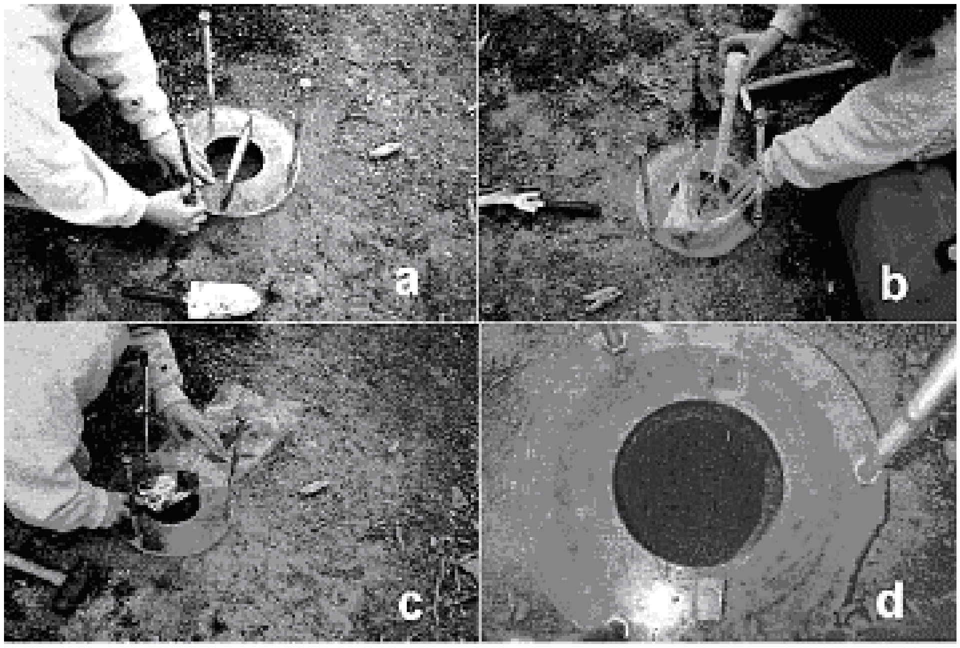


Figure 52. How to take a bulk density sample

Bulk Density Procedure -

Securing the Apparatus to the Ground

1. Place the apparatus foam-side-down on the ground.
2. Place the three securing rods in the 3/4" holes of the apparatus.
3. Drive each dowel into the ground until they do not move easily vertically or horizontally. (Figure 52a)

Leveling the Apparatus Horizontally to the Ground

1. Tighten each of the bolts until the apparatus appears level and the foam is compressed to a height of 1" to 1 1/2".
2. Place the bubble level on the surface of the apparatus and tighten or loosen the bolts in order to make the surface level. Place the level in at least three directions and on three different areas of the surface of the apparatus.

Determining the Volume from the Ground to the Hook Gauge

1. Pour exactly one liter of water into the graduated cylinder.
2. Pour some of the water into a plastic storage bag.
3. Hold the plastic bag so that the water goes to one of the lower corners of the bag.
4. Place the corner of the bag into the hole. Slowly lower the bag into the hole allowing the bag and the water to snugly fill all of the crevasses.

5. Slightly raise and lower the bag in order to eliminate as many air pockets as possible.
6. Lay the remainder of the bag around the hole.
7. Place the hook-gauge on the notches on the surface of the apparatus.
8. Add water to the bag until the surface of the water is just touching the bottom of the hook on the hook-gauge. A turkey-baster works very well to add and subtract small volumes of water. Be sure not to leave any water remaining in the turkey-baster. (Figure 52b)
9. Place the graduated cylinder on a flat surface. Read the cylinder from eye-level. The proper volume is at the bottom of the meniscus. Read the volume of the water remaining in the graduated cylinder. Record this volume. Subtract the remaining volume from the original 1000 ml to find the volume from the ground surface to the hook-gauge.
10. Carefully transfer the water from the bag to the graduated cylinder. Hold the top of the bag shut, except for two inches at either end. Then use the open end as a spout. (It is best to reuse water, especially when doing multiple tests in the field.)

Loosening the Soil and Digging the Hole

1. Label the oven-safe bag with the date and test number and other pertinent information using a permanent marker.
2. Loosen the soil. The hole should be approximately six cm deep and should have vertical sides and a flat bottom. (The hole should be a cylinder: with surface area the size of the hole of the apparatus and height of six cm.)
3. Remove the soil from the ground and very carefully place it in the oven-safe bag. (Be careful to lose as little soil as possible.) (Figure 52c and d)
4. Continue to remove the soil until the hole fits the qualifications.
5. Loosely tie the bag so that no soil is lost in transportation.

Finding the Volume of the Hole

1. Determine the volume from the bottom of the hole to the hook-gauge as described in **Determining the Volume from the Ground to the Hook-Gauge**. Record this volume. Reusing the water from the prior measurement presents no potential problems and is necessary when performing numerous experiments in the field.
2. Subtract the volume of the first measurement from the second volume measurement. The answer is the volume of the hole.

Calculating the Bulk Density of the Sample

1. Weigh the sample, and subtract the tare weight of the bag. Record the weight.
2. Dry the soil in an oven at 100°C for at least 24 hours.
3. Reweigh the sample, and subtract the tare weight of the bag. Record the weight.
4. Divide the mass of the sample by the volume of the hole. The result is the bulk density of the sample.

Calculating the Bulk Density of the Soil

We must determine the mass and volume of the rock fraction (> 2mm) of the sample and subtract these from the sample values in order to determine the density of the soil portion of the sample.

1. Place a sieve (2 mm mesh, #10) on a piece of paper. See Figure 53. Put the sample into the sieve. Carefully push the soil through the mesh. Be careful not to bend the wire mesh by forcing the rocks through. The rock fraction will stay on top of the sieve. Save the soil if you wish to do additional tests.
2. Weigh the rocks that are remaining on top of the sieve. Record this weight.
3. Place 500 ml of water into a 1000 ml graduated cylinder. Carefully add the rocks to the water. Read the volume of the water in the graduated cylinder. Record this volume.
4. Subtract the weight of the rocks from the weight of the sample, this will give you the weight of the soil.
5. Subtract the volume of the rocks from the volume of the sample, this will give you the volume of the soil.
6. Divide the weight of the soil by the volume of the soil. This gives you the bulk density of the soil.

Figure 53. Sieving the Sample

Potential Problems and Solutions

After I started digging I hit a large (>2 cm) rock. What should I do?
The best solution is to start over in another location. Also, you can remove the rock from the soil and subtract the volume of the rock from the total volume of the water. You should never include a rock in the density of the soil. Rocks have significantly higher densities than soil and will invalidate the results. Roots, corncobs, ants and even mole holes will also invalidate the results. If you find any of these things the best thing to do is start the test again at another site.

After I began digging the hole I noticed one of the dowels wasn't the apparatus firmly in place. Do I have to start over?

Unfortunately, if you have already started digging you do have to start the experiment again. Replacing the dirt to find the volume between the ground surface and the hook-gauge will give an inaccurate volume and thus an inaccurate soil density.

I noticed that the bag holding the water has a small leak. Is there anything I can do?
If the leak began after you had already found the volume, it is not necessary to start again. The volume is being measured in the graduated cylinder. If you have already removed the appropriate volume of water leaks in the bag, it will not affect the results of the test. However, if you noticed the leak before finding the volume, you will have to start again.

8.12 Surface Roughness

Photographs will be taken of the plot area at the time of sampling. These will be collected with a digital camera. A marker board will be used to mark the plot, field location, and date. Photographs will be collected at an oblique angle (30-45º from horizontal) and at nadir at a height of a minimum of 1 m above the canopy. Four photos will be taken in each plot in this order: marker board, oblique, and nadir (or as close as possible), and a synoptic field photo.

Surface roughness photographs will be obtained using the grid board approach. For grasses this should be performed after canopy and thatch removal. For row crops, photos will be taken both across (c) and along (a) the rows, the soil surface must be visible, therefore it may be necessary to remove plants, but do not damage more plants than you have to. Push the board into the soil surface so that there is no space between the board and the soil surface. Place a card with the site ID on the board and take a photo of the board and the soil surface in front of the board. (see Figure 54) Surface roughness photos will be taken once during the experiment unless there is a change in the field conditions (plowing, planting, harvesting …).

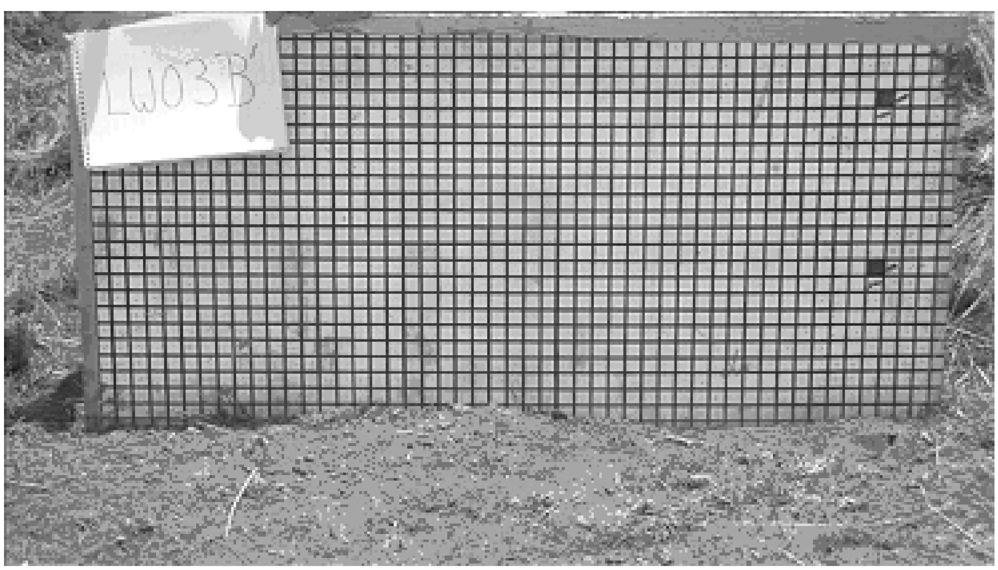


Figure 54. Surface Roughness Photo

8.13 Hydra Probe Soil Moisture and Apogee Temperature Sensor Installations

Figure 55 shows a close up of the Hydra probe. As with the installation of any soil moisture measuring instrument, there are two prime considerations: the location the probe is to be installed at, and the installation technique. A copy of the instruction manual for the HP will be available at he field HQ and can also be found at http://hydrolab.arsusda.gov.

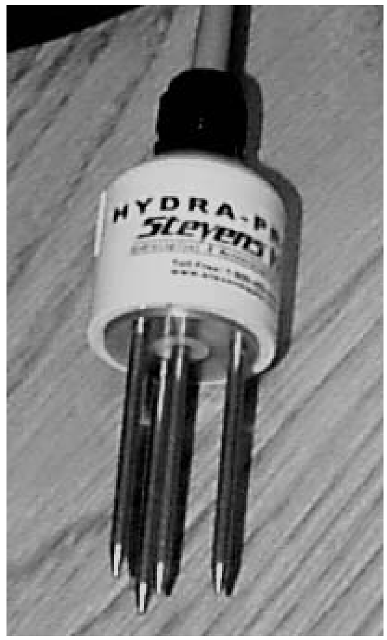


Figure 55. The Hydra probe used at the tower locations.

Selecting a Location for the HP

- The probe installation site should be chosen carefully so that the measured soil parameters are "characteristic" of the site.
- Make sure that the site will be out of foot traffic and is carefully marked and flagged.

Installation of the HP

- The installation technique aims to minimize disruption to the site as much as possible so that the probe measurement reflects the “undisturbed site” as much as possible.
    - Dig an access hole. This should be as small as possible.
    - After digging the access hole, a section of the hole wall should be made relatively flat. A spatula works well for this.
    - The probe should then be carefully inserted into the prepared hole section. The probe should be placed into the soil without any side to side motion which will result in soil compression and air gaps between the tines and subsequent measurement inaccuracies. The probe should be inserted far enough that the plane formed where the tines join the probe head is flush with the soil surface.

    - After placing the probe in the soil, the access hole should be refilled.
    - For a near soil surface installation, one should avoid routing the cable from the probe head directly to the surface. A horizontal cable run of 20 cm between the probe head and the beginning of a vertical cable orientation in near soil surface installations is recommended.
- Other general comments are below.
    - Avoid putting undue mechanical stress on the probe.
    - Do not allow the tines to be bent as this will distort the probe data
    - Pulling on the cable to remove the probe from soil is not recommended.
    - Moderate scratches or nicks to the stainless steel tines or the PVC probe head housing will not affect the probe's performance.

8.14 Vegetation Sampling

Overall protocol for each site

In Arizona, the plots will be located with GPS coordinates and flags before the intensive sampling around the date of the AVIRIS overflight. The plot dimensions will be 30 m by 30 m, which is 150% of the AVIRIS pixel size. Before dawn, the teams will drive to the selected study site so that in the twilight, canopy LAI can be measured with the LAI-2000. In addition, the following data will be collected: shrub/tree height, density, diameters and water content ground cover; plot spectral measurements; grass and forb plot clippings; and digital photographs, leaves of the dominant species will be clipped and transported to the laboratory for detailed measurements.

Plot cover

With a 30 m tape, lay out 5 transects across the plot, with transects evenly spaced five meters apart (go around any tree/shrub stumps and continue). Mark each transect with flags for use in spectral reflectances and LAI-2000 measurements. Starting at 1.0 m and ending at 29.0 m, for every 0.5 meter, record the cover at that point: bare soil, residue/litter, soil crust, succulent, shrub or tree by species (if possible, collectively for oaks), grass (collectively), forbs (collectively), etc.

Leaf area index with the LAI-2000

Measurements from the LAI-2000 are more accurate when the sky is uniformly lit; twilight at dawn and dusk and overcast with clouds are when uniform conditions are met. However, practical operations may require leaf area measurements under the sun.

The operating instructions for the LAI-2000 are in section 8.16

Shrub/tree density, diameter, height, and water content

Count each shrub or tree in the plot by species (if possible, collectively for oaks). When a shrub or tree is on the plot border, if the stem is mostly in the plot include it, if the stem is mostly out of the plot, exclude it, and if it falls halfway into the plot, then include the first, exclude the second, and alternate for any others. Measure the diameter of all included shrubs and trees to the nearest 1 cm with a diameter tape (if available) or measure the circumference with a regular cloth tape. Regressions will be used between diameter, density, and leaf area to obtain a second estimate of LAI.

Find a tree or shrub of the average height for the plot. Stand a known distance away (using the tape) and sight the angle between the base and the top with a clinometer. For small shrubs and grasses, a meter stick may be used.

Label 10 (or so) paper bags. For 10 randomly selected shrubs (use a random number table), clip one branch as near as possible to the main stem. At intervals cut a 5 cm segment and measure the fresh weight (nearest 0.01 g) and diameter with calipers (mm accuracy). Place all of the stem segments from one tree into one paper bag and leave in the sun to air dry. Later, these bags will be transported to Tucson or Hermosillo to dry in ovens.

Count succulents (cacti and yuccas) for density but don't measure diameters or measure stem water contents.

ASD plot spectral measurements

For grass plots, use a short-cabled ASD and for medium height shrubs use a long-cabled ASD with a extension pole. Run five transects evenly spaced 5 m apart, holding the foreoptics away from your body and pointing the foreoptics nadir. At the start of the transect, measure the digital number of a white spectralon panel. Then measure the digital number of the plot at 0.5 meter (about one small step) increments. At the end of the transect, again measure the digital number of the white spectralon panel. Calculate bidirectional reflectance factors by either averaging the two white panel readings, or linearly interpolating between the two readings, depending on the sun conditions.

Each transect should be saved with a different file name.

For areas of bare soil and for various plant species, measure the bidirectional reflectance factor using the white spectralon panel as a reference.

Grass plot and understory clippings

Label and weigh paper bags for grasses and forbs. Clip the green foliage from a constant ground area (0.5 m by 0.5 m) at ground level and put the clippings into the proper paper bag. Weigh the bag for fresh weight.

a. Start at SW point of plot, (or use mirror image for other starting location)
b. Walk 10 paces N (about 5 m) and 10 paces E, place 1st point
c. Walk 10 paces in N direction, place 2nd point
d. Walk 10 paces in E direction, place 3d point
e. Walk 10 paces in N direction, place 4th point
f. Walk 10 paces in E direction, place 5th point
g. Walk 10 paces in S direction, place 6th point

Leave the bags in the sun to air dry. In AZ, these bags will periodically be transported to Tucson or Hermosillo to dry in a large oven.

Digital Photographs

At each plot, photographs of the dominant vegetation should be made. Digital cameras with fish-eye lens will be used to take canopy photographs. At the Desert Research Institute (Reno, Nevada), foliar cover in the photographs was found to be highly correlated with LAI. For the AZ sites, these fish-eye photographs will be compared to the LAI measured with the LAI-2000 and with biomass samples. Since the fish-eye photographs can be taken during the day, and twilight measurements with the LAI-2000 may be difficult to make at the SO sites because of travel conditions, the fish-eye measurements may be provide the better LAI measurements at the SO sites. At least 15 photographs will be taken at each site, and foliar cover will be estimated from a supervised classification of the digital photographs.

Leaf EWT, SLA, and reflectances

In the field, plastic bags will be labeled with a marker and weighed to the nearest 0.01 g. Then, a leaf or a clump of leaves of the dominant species will be covered in the plastic bag (to reduce water loss) and clipped. The fresh weight of the leave(s) will be measured. The leave(s) will be stored in a cooler for transport back to the lab. At least 10 samples should be obtained at each plot.

In the lab, the bag with the leave(s) will be weighed again (0.001 g accuracy) to determine water loss during transport. The leave(s) will be removed from the bag, and spread out on a black painted surface. With a scale indicator in the field of view, a digital photograph will be taken at close range; the photograph will be analyzed for total leaf area.

An Analytical Spectral Devices (ASD) spectroradiometer will be used to measure bidirectional reflectance factors using the light from a window or an incandescent lamp. If the leaves are small, several leaves need to be in the field of view (FOV) of the spectroradiometer. The area of the FOV can be determined from the foreoptics (bare fiber optic tip has a 50% FOV, which is a diameter of 5 cm from a distance of 10 cm). An overhead transparency with a 0.5 cm grid (xeroxed), with the FOV circled, is used to estimate the fraction of leaves covering the FOV (1 - visible grid points/total grid points). The reflectance spectrum of the leaves can be determined from simple linear mixing:

$$R_\lambda(\text{total}) = f\, R_\lambda(\text{leaf}) - (1-f)\, R_\lambda(\text{background})$$

where R_λ is the reflectance at wavelength λ, and f is the fraction of leaves in the FOV. The background should have low reflectance at all wavelengths to prevent multiple scattering, which causes nonlinear mixing. Black paper or black cloth usually has high reflectance in the near infrared and shortwave infrared.

The mass of liquid water in the leaves is determined by subtracting the fresh weight by the dry weight. Drying should be in a small oven set to about 40 °C to prevent volatilization of organic compounds. A small oven for drying these leaf samples will be available.

Tree water contents

For the riparian mesquite and cottonwood plots, label and weigh 5 plastic bags. Wood cores to the center of the tree should be taken from 5 randomly selected trees with a increment borer. Age of the tree is determined from counting the annual growth rings. Sapwood is the functioning xylem (translucent because the vessels and tracheids are water filled) starting at the cambium and going inward towards the center. The length of sapwood between the cambium and non-functional xylem should be measured to the nearest millimeter. Most of the error will be from determining the transition between sapwood and non-functioning xylem. Sapwood area based on density, diameter, and sapwood length is biophysically related to LAI. to After the sapwood length is measured, measure the fresh weight of the increment core. Diameters of the trees must be cross-referenced with the cores. Oven dry the increment cores for dry weight. Fresh weight and dry weight of the cores will be used to estimate stem water contents.

Equipment list

Individual team equipment

- ASD spectroradiometer (long or short cable)
    - a. long cable with extension pole to get above the canopy
    - b. spectralon panel for calibration
- LAI-2000 (two)
- Portable digital balance (0.01 g accuracy, extra batteries)
- GPS/map
- Cellphone
- Digital camera for photographs
- Digital camera with fish-eye lens for LAI measurments
- Two tape measures (>30 m)
- Orange flags to mark transects
- Inclinometer or angle finder
- Machete
- Pole pruner (for woodlands)
- Grass clippers
- Sissors
- Loping shears (for woodlands)
- Hand shears
- Increment borer
- Calipers (0.1 mm accuracy)
- Diameter tape or cloth tape measure for circumference
- Meter stick
- Frame (0.5 m by 0.5 m)
- Paper lunch bags
- Plastic ziploc bags

Marker pens
Cooler with small blue ice container

Group equipment
Small oven for drying samples
Electronic balance to 0.001 g accuracy
Black painted backgrounds for leaf area
Scale indicators (squares of known area)
Transparencies with grid lines 5 mm square
Incandescent lamps
Power strips

8.15 Ground Surface Reflectance

Surface reflectance data is valuable in developing methods to estimate the vegetation water content and other canopy variables. Observations made concurrent with biomass sampling provide the essential information needed for larger scale mapping with satellite observations. In addition, reflectance measurements made concurrent with satellite overpasses allow the validation of reflectance estimates based upon correction algorithms.

For SMEX04, we are using instruments developed by CROPSCAN (http://www.cropscan.com). Most hand-held radiometers, which are used to measure soil and plant reflectance in the field, have one detector that must be calibrated frequently for changing amounts of sunlight. Dual-detector instrument designs measure the amount of sunlight and the reflected light simultaneously; thus, fewer calibrations are required and data may be acquired rapidly. The CROPSCAN Multispectral Radiometer (MSR) is an inexpensive instrument that has up-and-down-looking detectors and the ability to measure sunlight at different wavelengths. The basis instrument is shown in Figure 56.

The CROPSCAN multispectral radiometer systems consist of a radiometer, data logger controller (DLC) or A/D converter, terminal, telescoping support pole, connecting cables and operating software. The radiometer uses silicon or germanium photodiodes as light transducers. Matched sets of the transducers with filters to select wavelength bands are oriented in the radiometer housing to measure incident and reflected irradiation. Filters of wavelengths from 450 up to 1720 nm are available.

Figure 56. CROPSCAN Multispectral Radiometer (MSR). (Size is 8 X 8 X 10 cm).

For SMEX04 we will be using a MSR16R unit with the following set of bands:

Satellite	*ID*	*CenterWavelength (Bandwidth)*
Thematic Mapper	MSR16R-485TMU	485 nm up sensor (90 nm BW)
	MSR16R-485TMD	485 nm down sensor (90 nm BW)
	MSR16R-560TMU	560 nm up sensor (80 nm BW)
	MSR16R-560TMD	560 nm down sensor (80 nm BW)
	MSR16R-660TMU	660 nm up sensor (60 nm BW)
	MSR16R-660TMD	660 nm down sensor (60 nm BW)
	MSR16R-830TMU	830 nm up sensor (140nm BW)
	MSR16R-830TMD	830 nm down sensor (140nm BW)
	MSR16R-1650TMU	1650 nm up sensor (200nm BW)
	MSR16R-1650TMD	1650 nm down sensor (200nm BW)
MODIS	MSR16R-650U2	650 nm up sensor (40 nm BW)
	MSR16R-650D2	650 nm down sensor (40 nm BW)
	MSR16R-850U2	850 nm up sensor (60 nm BW)
	MSR16R-850D2	850 nm down sensor (60 nm BW)
	MSR16R-1240U	1240 nm up sensor (12 nm BW)
	MSR16R-1240D	1240 nm down sensor (12 nm BW)
	MSR16R-1640U	1640 nm up sensor (16 nm BW)
	MSR16R-1640D	1640 nm down sensor (16 nm BW)

These bands provide data for selected channels of the Landsat Thematic Mapper and MODIS instruments. Channels were chosen to provide NDVI as well as a variety of vegetation water content indices under consideration.

In the field the radiometer is held level by the support pole above the crop canopy. The diameter of the field of view is one half of the height of the radiometer above the canopy. It is assumed that the irradiance flux density incident on the top of the radiometer (upward facing side) is identical to the flux density incident on the target surface. The data acquisition program included with the system facilitates digitizing the voltages and recording percent reflectance for each of the selected wavelengths. The program also allows for averaging multiple samples. Ancillary data such as plot number, time, level of incident radiation and temperature within the radiometer may be recorded with each scan.

Each scan, triggered by a manual switch or by pressing the space key on a terminal or PC, takes about 2 to 4 seconds. An audible beep indicates the beginning of a scan, two beeps indicate the end of scan and 3 beeps indicate the data is recorded in RAM. Data recorded in the RAM file are identified by location, experiment number and date.

The design of the radiometer allows for near simultaneous inputs of voltages representing incident as well as reflected irradiation. This feature permits accurate measurement of reflectance from crop canopies when sun angles or light conditions are less than ideal. Useful measurements of percent reflectance may even be obtained during cloudy conditions. This is a very useful feature, especially when traveling to a remote research site only to find the sun obscured by clouds.

Three methods of calibration are supported for the MSR16R systems.

2-point Up/Down - Uses a diffusing opal glass (included), alternately held over the up and down sensors facing the same incident irradiation to calibrate the up and down sensors relative to each other (http://www.cropscan.com/2ptupdn.html).
Advantages:
- Quick and easy.
- Less equipment required.
- Radiometer may then be used in cloudy or less than ideal sunlight conditions.
- Recalibration required only a couple times per season.
- Assumed radiometer is to be used where radiance flux density is the same between that striking the top surface of the radiometer and that striking the target area, as outside in direct sunlight.

White Standard Up & Down - Uses a white card with known spectral reflectance to calibrate the up and down sensors relative to each other.
Advantages:
- Provides a more lambertian reflective surface for calibrating the longer wavelength (above about 1200 nm) down sensors than does the opal glass diffuser of the 2-point method.
- Radiometer may then be used in cloudy or less than ideal sunlight conditions.
- Recalibration required only a couple times per season.
- Assumed radiometer is to be used where radiance flux density is the same between that striking the top surface of the radiometer and that striking the target area, as outside in direct sunlight.

White Standard Down Only - Uses a white card with known spectral reflectance with which to compare down sensor readings.
Advantages:
- Only down sensors required, saving cost of purchasing up sensors.
- Best method for radiometer use in greenhouse, under forest canopy or whenever irradiance flux density is different between that striking the top of the radiometer and that striking the target area.

Disadvantages:
- White card must be carried in field and recalibration readings must be taken periodically to compensate for sun angle changes.
- Less convenient and takes time away from field readings.

Readings cannot be made in cloudy or less than ideal sunlight conditions, because of likely irradiance change from time of white card reading to time of sample area reading.

Figure 57 – data logger controller & cable adapter box.

There are six major items you need in the field -

- MSR16 (radiometer itself) (Figure 56)
- Data Logger Controller & Cable Adapter Box (carried in the shoulder pack, earphones are to hear beeps) (Figure 57)
- CT100 (hand terminal, connected to the DLC with a serial cable) (Figure 58)
- Calibration stand and opal glass plate
- Memory cards
- Extension pole (with spirit level adjusted so that the top surface of the radiometer and the spirit level are par level)

Figure 56. CT100 hand terminal.

Set Up –

- Mount the radiometer pole bracket on the pole and attach the radiometer.
- Mount the spirit level attachment to the pole at a convenient viewing position.

- Lean the pole against a support and adjust the radiometer so that the top surface of it is level
- Adjust the spirit level to center the bubble (this will insure that the top surface of the radiometer and the spirit level are par level)
- Attach the 9ft cable MSR87C-9 to the radiometer and to the rear of the MSR Cable Adapter Box (CAB)
- Connect ribbon cables IOARC-6 and IODRC-6 from the front of the CAB to the front of the Data Logger Controller (DLC)
- Plug the cable CT9M9M-5 into the RS232 connectors of the CT100 and the DLC (the DLC and CAB may now be placed in the shoulder pack for easy carrying)
- Mount the CT100 on the pole at a convenient position
- Adjust the radiometer to a suitable height over the target (the diameter of the field of view is one half the height of the radiometer over the target)

Configure MSR –

- Perform once at the beginning of the experiment, or if the system completely loses power
- Switch the CT100 power to on
- Press **ENTER** 3 times to get into main menu
- At Command * Press **2** then **ENTER** to get to the Reconfigure MSR menu
- At Command * Press **1** then **ENTER**, input the correct date, Press **ENTER**
- At Command * Press **2** then **ENTER**, input the correct time, Press **ENTER**
- At Command * Press **3** then **ENTER**, input the number of sub samples/plot (5), Press **ENTER**
- At Command * Press **6** then **ENTER**, input a 2 or 3 character name for your sampling location (ex OS for Oklahoma South), Press **ENTER;** input the latitude for your location, Press **ENTER;** input the longitude for your location, Press **ENTER**
- At Command * Press **9** then **ENTER**, input the GMT difference, Press **ENTER**
- At Command * Press **M** then **ENTER** until you return to the main menu
-

Calibration –

- ***We are using the 2-point up/down calibration method***
- Calibrate everyday before you begin to take readings
- Switch the CT100 power to on
- Press **ENTER** 3 times to get into main menu
- At Command * Press **2** then **ENTER** to get to the Reconfigure MSR menu
- At Command * Press **11** then **ENTER** to get to the Calibration menu
- At Command * Press **3** then **ENTER** to get to the Recalibration menu
- At Command * Press **2** then **ENTER** for the 2-point up/down calibration
- Remove the radiometer from the pole bracket and place on the black side of the calibration stand, point the top surface about 45° away from the sun, press **SPACE** to initiate the scan (1 beep indicates the start of the scan, 2 beeps indicate the end of the scan, and 3 beeps indicate the data was stored)
- Place the separate opal glass plate on top of the upper surface and press **SPACE** to initiate scan

- Turn the radiometer over and place it back in the calibration stand, cover it with the separate opal glass plate and press **SPACE** to initiate scan
- CT100 will acknowledge that the recalibration was stored
- At Command * Press **M** then **ENTER** until you return to the main menu
- Return the radiometer to the pole bracket
- Store configuration onto the memory card

Memory Card Usage –

- Switch the CT100 power to on
- Press **ENTER** 3 times to get into main menu
- At Command * Press **7** then **ENTER** to get to the Memory Card Operations menu
- Memory Card Operations menu is:
  1. Display directory
  2. Store data to memory card (use to save data in the field)
  3. Load data from memory card (use first to download data from memory card)
  4. Save program/configuration to card (use to save after calibrating)
  5. Load program/configuration from card (use when DLC loses power)
  6. Battery check

  M Main menu
- There are 2 memory cards, 64K for storing the program/configuration and 256 for storing data in the field

Taking Readings in the Field –

- Switch the CT100 power to on
- Press **ENTER** 3 times to get into main menu
- At Command * Press **2** then **ENTER** to get to the Reconfigure MSR menu
- At Command * Press **5** then **ENTER,** input your plot ID (numbers 1-999 only), Press **ENTER**
- Press **M** to return to the MSR main menu
- At Command * Press **8** then **ENTER** to get to the MSR program
- Press **ENTER** to continue or **M** to return to the MSR main menu
- Enter beginning plot number, **ENTER**
- Enter the ending plot number**, ENTER**, record plot numbers and field ID in field notebook
- Adjust the radiometer to a suitable height (about 2 meters) over the target, point the radiometer towards the sun, center the bubble in the center of the spirit level and make sure that there are no shadows in the sampling area
- **Do not** take measurements if IRR < 300
- Initiate a scan by pushing **SPACE,** the message 'scanning' will appear on the screen and a beep will be heard
- When the scan is complete (about 2 seconds) '**' will be displayed and 2 beeps will be heard
- Now, you can move to the next area
- 3 Beeps will be heard when the data has been stored

- Press **SPACE** to start next scan, **R** to repeat scan, **P** to repeat plot, **S** to suspend/sleep, **M** to return to the MSR main menu, **W** to scan white standard, and **D** to scan Dark reading
- When you are done scanning at that field location, press **M** to return to the MSR main menu, then press **10** to put the DLC to sleep
- Switch the CT100 power off

Downloading Data –
- Plug the cable RS9M9F-5 into the RS232 connectors on the front DLC and the serial port of your PC
- Start the Cropscan software on the PC
- Choose RETRIEVE from the menu and press **ENTER**
- Select your PC COM port and press **ENTER**
- Enter your file name (MMDDFL.MV, where MM is month, DD is day, FL is first and last initials of user and MV for raw millivolt data files)
- After the data is downloaded, press **Y then ENTER** to clear the data from the DLC

Two types of sampling will be performed as part of SMEX04:

Vegetation Water Content Sampling Location:
Reflectance and LAI data will be collected for each vegetation sampling location (Figure 59) just prior to removal using the following sampling scheme.

Take a reading every 5 meters for 25 meters. Repeat, for a total of 3 replications located 10 meters apart.

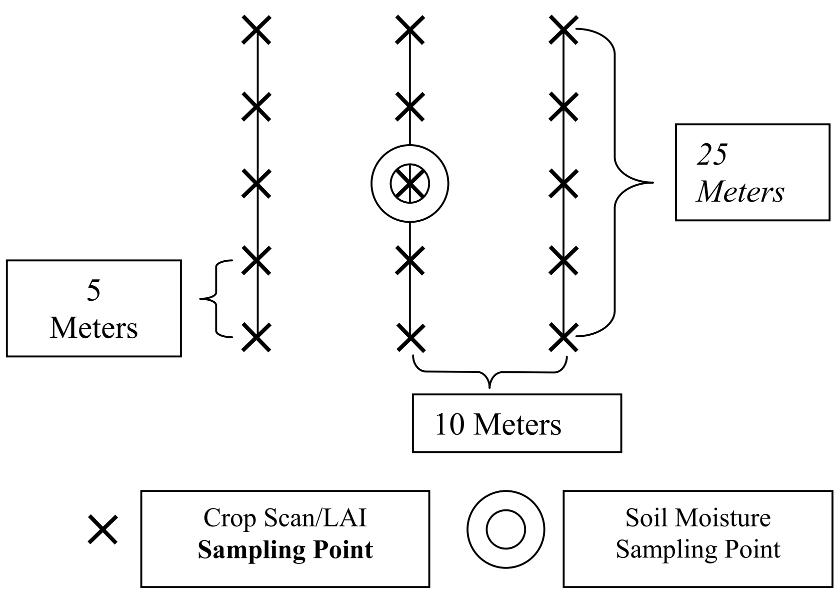


Figure 59. Vegetation sampling scheme.

Field Transect:
Each different land use type (shrubs, grasslands, etc...) will be characterized by transect sampling. Reflectance and LAI measurement will be collected at representative sites. (Figures 60 and 61). This will be done weekly, to coincide with the Landsat and ASTER overpasses. The following sampling scheme will be used for transect sampling.

Take a reading every 5 meters for 25 meters, walk 75 meters, continue until you have gone 400 meters. Walk over 100 meters. Do an other 400 meter transect.

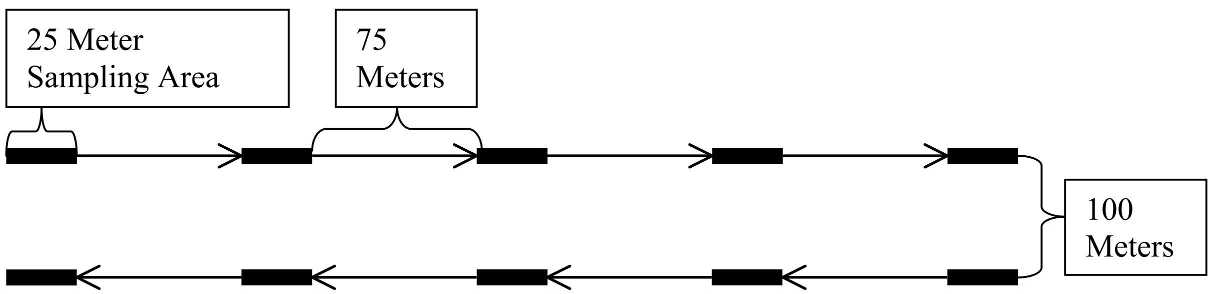


Figure 60. Transect sampling scheme.

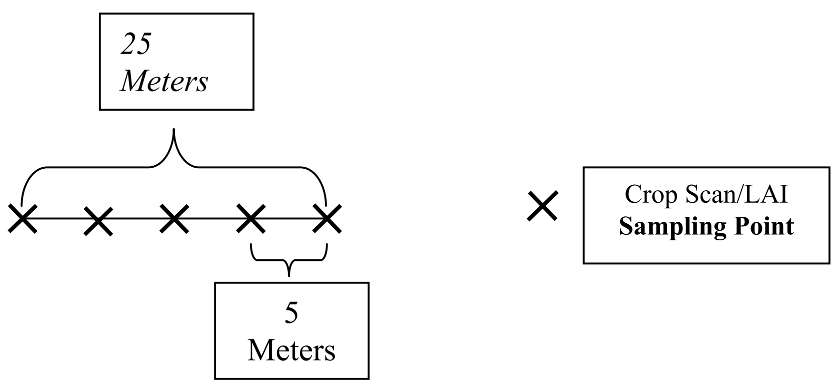


Figure 61. Enlarged transect sampling area.

8.16 Leaf Area Index

Leaf area will be measured with a LAI-2000 (Figure 62). The LAI-2000 will be set to average 5 points into a single value so one observation is taken above the canopy and 4 beneath the canopy. For *grasses and weeds and non-row crops*, three sets of measurements (each set consisting of 1 above the canopy and 5 beneath the canopy) will be made. Measurements will be taken every 5 meters on 25 meter transects.

If the sun is shining, the observer needs to stand with their back to the sun and put a black lens cap that blocks ¼ of the sensor view in place and positioned so the **sun and the observer are never in the view of the sensor**. The observer should always note if the sun was obscured during the measurement, whether the sky is overcast or partly cloudy with the sun behind the clouds. If no shadows could be seen during the measurement, then the measurement is marked “shaded”, if shadows could be seen during the measurement then the measurement is marked “sunny”. Conditions should not change from cloudy to sunny or sunny to cloudy in the middle of measurements.

Figure 62. The LAI-2000 instrument.

<u>Operating the LAI-2000 -</u>

Plug the sensor cord into the port labeled “X” and tighten the two screws.

Place a black view-cap over the lens that blocks 1/4 of the sensor view; that 1/4 that contains the operator. Place a piece of tape on the view cap and body of the sensor so if the cap comes loose it will not be lost.

Turn on the logger with the “**ON**” key (The unit is turned off by pressing “**FCT**”, "**0**" , "**9**".)

Clear the memory of the logger -

Press “**FILE**”
Use “↑” to place “Clear Ram” on the top line of display
Press “**ENTER**”
Press “↑” to change “NO” to “YES”
Press “**ENTER**”

General items –

When changing something on the display, get desired menu item on the top line of display and then it can be edited.

Use the “↑” and “↓” to move items through the menu and the “**ENTER**” key usually causes the item to be entered into the logger.

When entering letters, look for the desired letter on the keys and if they are on the lower part of the key just press the key for the letter; if the desired letter is on the upper part of the key then press the “↑” and then the key to get that letter.

Press “**BREAK**” anytime to return to the monitor display that contains time, file number or sensor readings on one of the five rings that are sensed by the LAI-2000.

Do not take data with the LAI-2000 if the sensor outputs are less than 1.0 for readings above the canopy.

To Begin -

Press “**SETUP**”

Use “↑” to get “XCAL” on the top line of the display and press “**ENTER**”
Following XS/N is the serial number of the sensor unit, enter appropriate number
Check or put appropriate cal numbers from LICOR cal sheet into the 5 entries.
Final press of “**ENTER**” returns you to “XCAL”

Use “↑” to get to “RESOLUTION”
Set it to “HIGH”

Use “↑” to get to “CLOCK”
Update the clock (set to local time using 24 hr format)

Press “**OPER**”

Use “↑” to get “SET OP MODE” on top line of display
Choose “MODE=1 SENSOR X”
Enter “↑”, “↓”, “↓”, “↓”, “↓” in “SEQ”
Enter "1" in “REPS”

Use “↑” to get to “SET PROMPTS”
Put “SITE” in first prompt
Put “LOC” in second prompt

Use “↑” to get to “BAD READING”
Choose "A/B=1"

Press “**BREAK**”

Display will contain the two monitor lines

Use “↑” and “↓” to control what is displayed on the top line in the monitor mode, time, file number or sensor ring output 1 through 5 for the X sensor. (If FI is selected, then the file number is displayed)

Use the "→" and "←" to control what is displayed on the bottom line of the monitor mode, time, file number or sensor ring output 1 through 5 for the X sensor. (If X2 is selected, then ring #2 output is displayed)

Press "**LOG**" to begin collecting data

Type in the response to the first prompt (if "**ENTER**" is pressed the same entry is kept in response to the prompt).

Type in the response to the second prompt (if "**ENTER**" is pressed the same entry is kept in response to the prompt).

Place the sensor head in the appropriate position above the canopy, level the sensor and press the black log button on the handle of the sensor (a beep will be heard when the black button is pushed). Hold the sensor level until the second beep is heard.

For Row crops –

1. Place the sensor head in the appropriate position above the canopy, level the sensor and press the black log button on the handle of the sensor (a beep will be heard when the black button is pushed). Hold the sensor level until the second beep is heard.
2. Place the sensor below the canopy in the row of plants, level the sensor and press the black log button on the sensor handle and keep level until the second beep.
3. Place the sensor one-quarter (1/4) of the way across the row and record data again.
4. Place the sensor one-half (1/2) of the way across the row and record data again.
5. Place the sensor three-quarters (3/4) of the way across the row and record data again.

Repeat steps 1-5 so that you have a total of 5 sets of measurements.

For Other Types of Vegetation –

1. At your starting spot, place the sensor head in the appropriate position above the canopy, level the sensor and press the black log button on the handle of the sensor (a beep will be heard when the black button is pushed). Hold the sensor level until the second beep is heard.
2. Place the sensor below the plant canopy in the same place level the sensor and press the black log button on the sensor handle and keep level until the second beep.
3. Repeat step 2 every 5 meters, for a total of 1 up and 5 down measurements.
4. Repeat for a total of 3 transects.
5. See figures 58 – 59 for detailed sampling schemes.

The logger will compute LAI and other values automatically. Using the "↑" you can view the value of the LAI.

NOTE: You will record the "SITE" and "LOC" along with the LAI value on a data sheet.

The LAI-2000 is now ready for measuring the LAI at another location. Begin by pressing "**LOG**" twice. The file number will automatically increment.

When data collection is complete, turn off the logger by pressing "**FCT**", "**0**", "**9**". The data will be dumped onto a laptop back at the Field Headquarters.

Downloading LAI-2000 files to a PC Using HyperTerminal -

Before beginning use functions 21 (memory status) and 27 (view) to determine which files you want to download. Make a note of their numbers.

1) Connect wire from LAI-2000 (25pin) to PC port (9 pin).

2) Run HyperTerminal on the PC (Start | Programs | Accessories | Communications | HyperTerminal | LAI2000.ht)

3) On the LAI-2000, go to function 31 (config i/o) and configure I/O options. Baud=4800, data bits=8, parity=none, xon/xoff=no.

4) On the LAI-2000, go to function 33 (set format) and setup format options. First we use Spdsheet and take the default for FMT.

5) In HyperTerminal go to Transfer | Capture text. Choose a path and filename (LAIMMDDFL.SPR, where MM is month, DD is day, FL is first and last initials of user and SPR for spreadsheet data files) to store the LAI data. Hit Start. HyperTerminal is now waiting to receive data from the LAI-2000.

6) On the LAI-2000, go to function 32 (print) and print the files. 'Print' means send them to the PC. You will be asked which file sequence you want. Eg. Print files from:1 thru:25 will print all files numbered 1-25. Others will not be downloaded.

7) Once you hit enter in function 32, lines of text data will be sent to HyperTerminal. The LAI-2000 readout will say 'Printing file 1, 2, etc'. Check the window in HyperTerminal to ensure the data is flowing to the PC. This may take a few minutes, wait until all the desired files have been sent.

8) In HyperTerminal go to Transfer | Capture text | Stop.

9) On the LAI-2000, go to function 33 (set format) and setup format options. Now set to Standard, Print Obs = yes

10) In HyperTerminal go to Transfer | Capture text Choose a path and filename (LAIMMDDFL.STD, where MM is month, DD is day, FL is first and last initials of user and STD for standard data files) to store the LAI data. Hit Start. HyperTerminal is now waiting to receive data from the LAI-2000.

11) On the LAI-2000, go to function 32 (print) and print the files. ‘Print’ means send them to the PC. You will be asked which file sequence you want. Eg. Print files from:1 thru:25 will print all files numbered 1-25. Others will not be downloaded.

12) In HyperTerminal go to Transfer | Capture text | Stop.

13) Using a text editor (like notepad) on the PC, open and check that all the LAI data has been stored in the text file specified in step 3. Make a back up of this file. Once you’re sure the LAI values look reasonable and are stored in a text file on the PC, use function 22 on the LAI-2000 to delete files on the LAI-2000 and free up it’s storage space.

Note: The above instructions assume that HyperTerminal has been configured to interface with the LAI-2000, i.e. the file LAI2k.ht exists. If not, follow these instructions to set it up.

1) Run HyperTerminal on the PC (Start | Programs | Accessories | Communications | HyperTerminal | Hypertrm

2) Pick a name for the connection and choose the icon you want. Whatever you pick will appear as a choice in the HyperTerminal folder in the start menu later. Hit OK.

3) Connect using com1 or com2. Choose which is your com port, hit OK. Setup Port settings as follows: Bits per second = 4800, Data Bits = 8, Parity = none, Stop bits = 1, Flow control = Hardware. Say OK.

4) Make sure the wire is connected to the LAI-2000 and the PC and proceed with step 3 in the download instructions above. When finished and leaving HyperTerminal you will be prompted to save this connection.

8.17 Global Positioning System (GPS) Coordinates

The geographic coordinates of all soil, vegetation, and micrometeorological sample sites need to be collected in order to map their locations in a geographic information system (GIS). A Garmin **e**Trex "sportsman" GPS will be used to collect the position data. This unit has the capacity to store up to 500 geographic coordinates or waypoints and is designed so that all key entries can be performed with the left hand alone. Accurate GPS data can be acquired 24 hours a day under all weather conditions. The only restraint is that the **e**Trex antenna--location determination is made at the site of the internal antenna--must have a clear view of the sky in all directions. Once accurate location data at a particular sample site has been acquired and confirmed, no additional GPS measurements at that site will be needed.

- All sampling points will be located using a handheld GPS including
    - Soil samples
    - Vegetation samples
    - Flux towers
    - Met stations

- To the extent possible, a single individual should make all of the readings. This person can be assigned to different teams on different days or use field markings provided by the teams.

General Information

Record site ID, and latitude and longitude coordinates in field notebook. Carry at least two (2) extra AA alkaline batteries. The **e**Trex is configured to run in Battery Save mode which automatically turns the GPS receiver on and off to conserve power. In this mode, the eTrex should operate for approximately 22 hours. A "Battery Low" message will appear at the bottom of the screen when the unit has ten (10) minutes of battery life remaining.

eTrex GPS Features (see Figure 63)

UP/DOWN ARROW buttons: used to select options.
ENTER button: used to confirm selections or data entry.
PAGE button: switches between display screens (or "pages") and also functions as escape key.
POWER button: turns **e**Trex GPS as well as display backlight on and off.

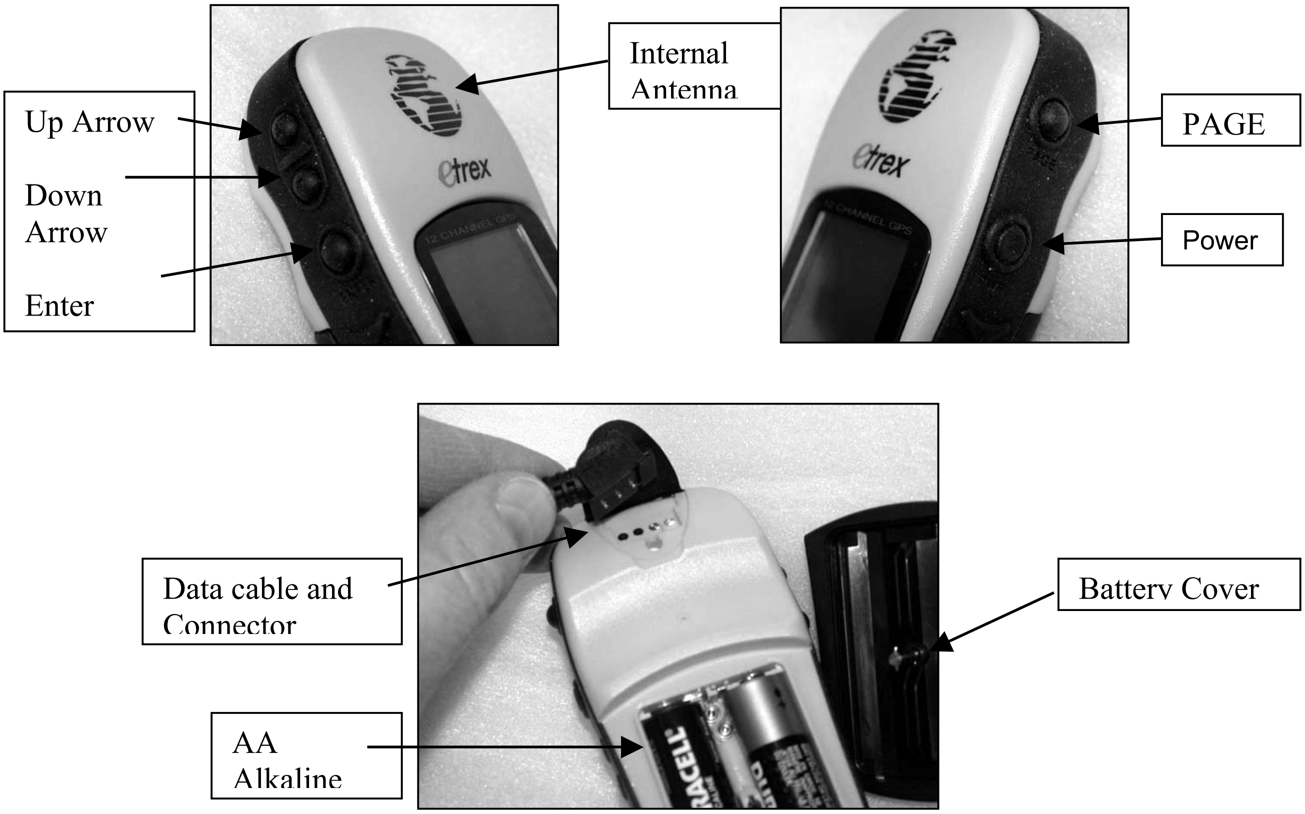


Figure 63. GPS features.

All eTrex operations are carried out from the four (4) “pages” (or display screens) shown in Figure 64. The PAGE key is used to switch between pages. (The Map and Pointer Pages are used for navigation and will not be discussed further.)

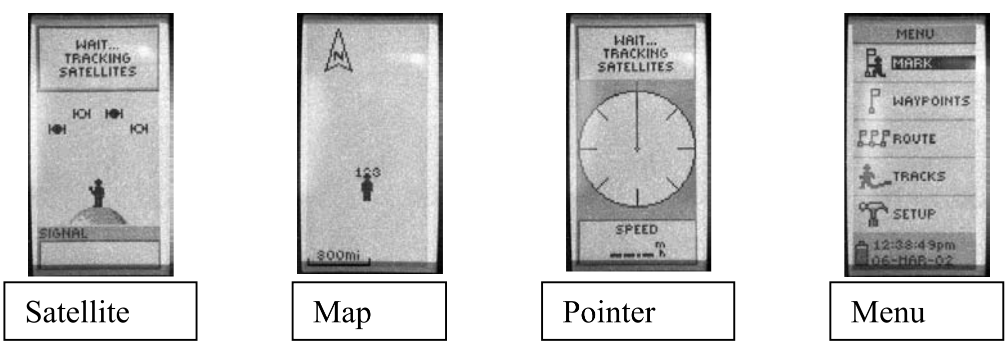


Figure 64. GPS display screens or “pages”.

<u>Setup at Headquarters Prior to Data Collection</u>

1. Power unit on: Depress and hold power button until eTrex welcome screen appears and Satellite Page is displayed.

2. Confirm configuration parameters:
   - PAGE to Menu screen; ARROW to Setup; press ENTER (Figure 65)
   - Use the following key sequence to check configuration parameters:
     - ARROW to first parameter; press ENTER;
     - confirm values (see configuration values below);
     - press PAGE to return to Setup menu;
     - ARROW to next parameter; press enter, repeat above steps for all parameters.
   - The following are the parameters and required settings;
     - Time = Format: **24 Hour**;
     - Zone: US-Mountain, (UTC Offset: **-7:00**);
       -
     - Daylight Saving: **No**
     - Display = Timeout: **15 sec.**
     - Units = Position Format: **hddd.ddddd°**; Map Datum: **WGS 84**; Units: **Metric**; North Reference: **True**
     - Interface = I/O Format: **Garmin**
     - System = Mode: **Battery Save**

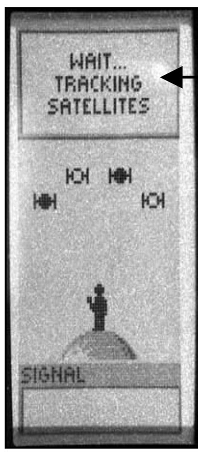
Figure 65. GPS menu page.

3. Turn **e**Trex off after GPS data collection by depressing and holding POWER button until screen blanks.

Important Note: Geodetic datums mathematically describe the size and shape of the earth and provide the origin and the orientation of coordinate systems used in mapping. Hundreds of datums are currently in use and particular attention must be paid to what datum is used during GPS data collection. The Global Positioning System is based on the World Geodetic System of 1984 (WGS84). However, popular map products such as USGS 1:24,000 topo sheets originally used the North American Datum of 1927 (NAD27). Most of the maps in this series have been updated to the North American Datum of 1983 (NAD83). Fortunately, there is virtually no practical difference between WGS84 and NAD83. Yet significant differences exist on the order of hundreds of meters between NAD27 and NAD83. *All geographic coordinates collected with the* ***e****Trex GPS should be acquired using the following parameters:* ***latitude/longitude (decimal degrees), WGS84 datum, meters, true north***. Coordinate conversion software packages such as NOAA's free Corpscon (http://www.ngs.noaa.gov/PC_PROD/pc_prod.shtml) exist which allow for the conversion of geodetic (latitude and longitude) coordinates into planar (UTM or State Plane) coordinates for GIS mapping.

GPS Field Data Collection

1. Power unit on: Depress and hold power button until eTrex welcome screen appears and Satellite Page is displayed (Figure 66). Wait until text box at top of screen reads "READY TO NAVIGATE" before continuing.



Wait until "READY TO NAVIGATE" is displayed
AND
Accuracy is <= 10 m
(Up to 5 minutes at a new location;
15-45 seconds on subsequent visits.)

Figure 66. GPS satellite page.

2. Adjust screen backlight and contrast, if necessary.
   - Turn backlighting on by quickly pressing and releasing POWER button from any screen. (To save power, the backlight remains on for only 30 seconds.); AND/OR,
   - Adjust screen contrast by pressing UP (darker) and DOWN (lighter) buttons from the Satellite Page.

3. Initiate GPS data collection:
   - PAGE to Menu screen (Figure 63); Arrow to Mark; press ENTER. (Shortcut: press and hold ENTER button from any screen to get to Mark Waypoint page below.)
   - ARROW to alphanumeric ID field (Figure 67); press ENTER. Use ENTER and UP/DOWN buttons to edit ID, if necessary. (Waypoint ID increments by one (1) automatically.)
   - Record latitude and longitude coordinates displayed at bottom of screen into field notebook. *Do not rely solely on electronic data download to save data points!*
   - ARROW to OK prompt; press ENTER to save point coordinates electronically.

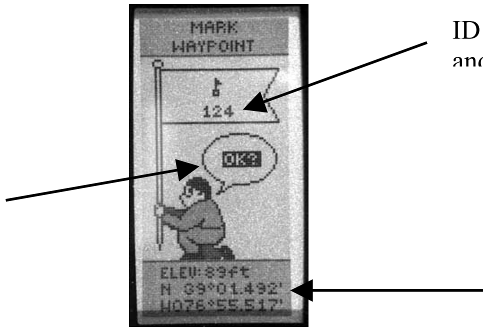


Figure 67. GPS Mark waypoint page.

4. Turn **e**Trex off after GPS data collection by depressing and holding POWER button until screen blanks.

<u>*Electronic Data Downloading*</u>

Electronic data downloading will be performed at field headquarters by assigned person.

Connect PC data cable by sliding keyed connector into shoe at top rear of eTrex (under flap); power eTrex on.
Launch Waypoint.exe
GPS => Port => Com<u>?</u>
Waypoints => Download
File => Save => Waypoint
Select Save as type: Comma Delimited Text File

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11 SMEX04 SATELLITE COVERAGE CALENDARS

Aqua/Coriolis/ASAR/Landsat/ASTER

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
7/11 Aqua/Coriolis *Day 193*	7/12 Coriolis *Day 194*	7/13 Aqua/Coriolis L5 *Day 195*	7/14 ASAR (6D) *Day 196*	7/15 Aqua *Day 197*	7/16 *Day 198*	7/17 Aqua/Coriolis ASAR (4D) *Day 199*
7/18 Aqua/Coriolis *Day 200*	7/19 Coriolis *Day 201*	7/20 Aqua ASAR(2A,2D) *Day 202*	7/21 ASTER *Day 203*	7/22 Aqua/Coriolis *Day 204*	7/23 Coriolis *Day 205*	7/24 Aqua/Coriolis *Day 206*
7/25 Aqua/Coriolis *Day 207*	7/26 *Day 208*	7/27 Aqua *Day 209*	7/28 Coriolis *Day 210*	7/29 Aqua/Coriolis L5 *Day 211*	7/30 Coriolis *Day 212*	7/31 Aqua *Day 213*
8/1 *Day 214*	8/2 Aqua ASAR (5D) *Day 215*	8/3 Aqua/Coriolis *Day 216*	8/4 Coriolis *Day 217*	8/5 Aqua/Coriolis ASAR(3D) *Day 218*	8/6 ASTER *Day 219*	8/7 Aqua *Day 220*
8/8 ASAR(2A) *Day 221*	8/9 Aqua/Coriolis *Day 222*	8/10 Aqua/Coriolis *Day 223*	8/11 Coriolis *Day 224*	8/12 Aqua *Day 225*	8/13 *Day 226*	8/14 Aqua/Coriolis L5 *Day 227*

MODIS (number in parentheses is the elevation angle from the horizon to the satellite)

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
7/11 Terra - Aqua 13:44:05(67.2) *Day 193*	7/12 Terra 11:14:44(78.8) Aqua - *Day 194*	7/13 Terra - Aqua 13:31:46(87.8) *Day 195*	7/14 Terra 11:02:30(75.6) Aqua - *Day 196*	7/15 Terra - Aqua 13:19:34(63.9) *Day 197*	7/16 Terra 10:50:16(54.0) Aqua 14:02:14(40.9) *Day 198*	7/17 Terra 11:32:55(48.4) Aqua 13:07:23(45.8) *Day 199*
7/18 Terra 10:37:55(38.8) Aqua 13:50:02(57.0) *Day 200*	7/19 Terra 11:20:41(67.5) Aqua - *Day 201*	7/20 Terra - Aqua 13:37:43(79.7) *Day 202*	7/21 Terra 11:08:28(86.9) Aqua - *Day 203*	7/22 Terra - Aqua 13:25:24(74.8) *Day 204*	7/23 Terra 10:56:06(63.7) Aqua - *Day 205*	7/24 Terra 11:38:45(41.4) Aqua 13:13:13(53.7) *Day 206*
7/25 Terra 10:43:49(45.4) Aqua 13:55:56(48.5) *Day 207*	7/26 Terra 11:26:27(57.4) Aqua 13:00:58(38.9) *Day 208*	7/27 Terra - Aqua 13:43:37(68.2) *Day 209*	7/28 Terra 11:14:14(79.8) Aqua - *Day 210*	7/29 Terra - Aqua 13:31:18(86.7) *Day 211*	7/30 Terra 11:02:00(74.7) Aqua - *Day 212*	7/31 Terra 11:44:31(35.6) Aqua 13:19:06(62.9) *Day 213*
8/1 Terra 10:49:39(53.3) Aqua 14:01:46(41.5) *Day 214*	8/2 Terra 11:32:17(48.9) Aqua 13:06:47(45.2) *Day 215*	8/3 Terra 10:37:25(38.3) Aqua 13:49:27(58.0 *Day 216*	8/4 Terra 11:20:03(68.3) Aqua - *Day 217*	8/5 Terra - Aqua 13:37:08(80.8) *Day 218*	8/6 Terra 11:07:50(86.5) Aqua - *Day 219*	8/7 Terra - Aqua 13:24:56(73.6) Day 220
8/8 Terra 10:55:32(62.7) Aqua 14:07:40(35.6) *Day 221*	8/9 Terra 11:38:03(41.9) Aqua 13:12:41(52.7) *Day 222*	8/10 Terra 10:43:11(44.7) Aqua 13:55:21(49.5) *Day 223*	8/11 Terra 11:25:49(58.2) Aqua 13:00:22(38.2) *Day 224*	8/12 Terra 11:25:49(58.2) Aqua 13:00:22(38.2) *Day 225*	8/13 Terra 11:13:36(80.9) Aqua - *Day 226*	8/14 Terra - Aqua 13:30:42(85.4) *Day 227*

12 LOGISTICS

The general region of southeastern Arizona and northwest Mexico is shown in Figure 68.

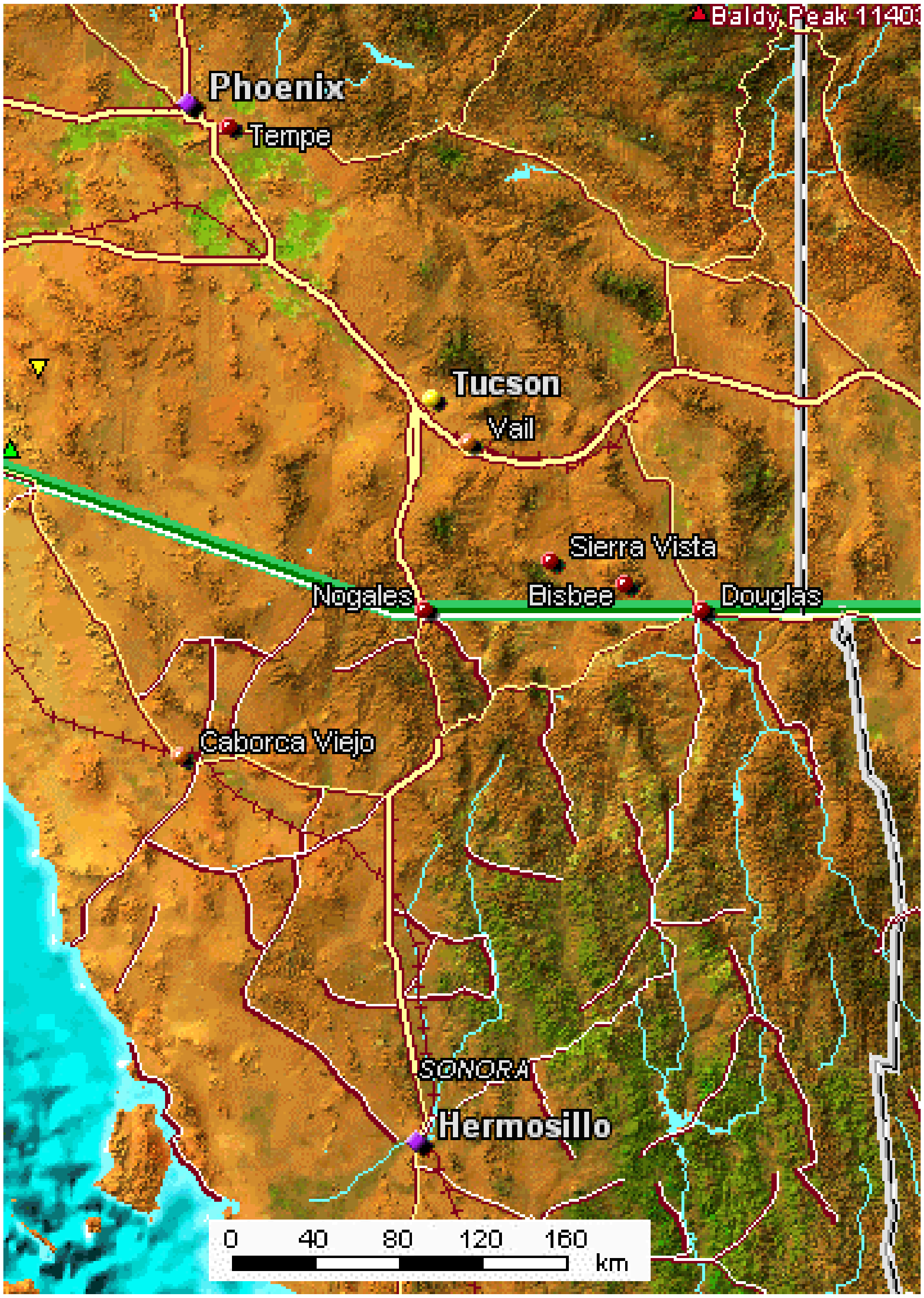

Figure 68. Arizona and Mexico.

12.1 P-3 Aircraft Operations

The NRL P-3 will operate out of Davis-Monthan AFB in Tucson, AZ. It is anticipated that all aircraft personnel will stay at the following hotel and that the daily briefing will be held at the hotel. See Figures 69 and 70. The expected hotel for this group is

Embassy Suites Hotel Tucson-Broadway
5335 E. Broadway Blvd.
Tucson, AZ 85711-3703
Tel: 1-520-745-2700
Fax: 1-520-790-9232
http://www.embassysuites.com/en/es/hotels/index.jhtml?ctyhocn=TUSBWES
Reservation code is NASA, Govt. rate if $58.

12.2 AZ Region and Tombstone, AZ

For sampling teams in the AZ region the following hotel is suggested in Tombstone

Holiday Inn Express Tombstone
1001 N Highway 80
PO Box 1730
Tombstone, AZ 85638
Tel: 1-520-457-9507
Fax: 1-520-457-9506
hiextombstone@yahoo.com
http://www.holidayinntombstone.com/ or
http://www.ichotelsgroup.com/h/d/ex/1/en/hd/omtaz?irs=null

There is a block of rooms under the code "USDA" at the rate of $49/night for a single or a double. You need to call the hotel directly and talk to the hotel manager Brenda Sharkey. Figure 71 and 72 show the location of Tombstone and the hotel.

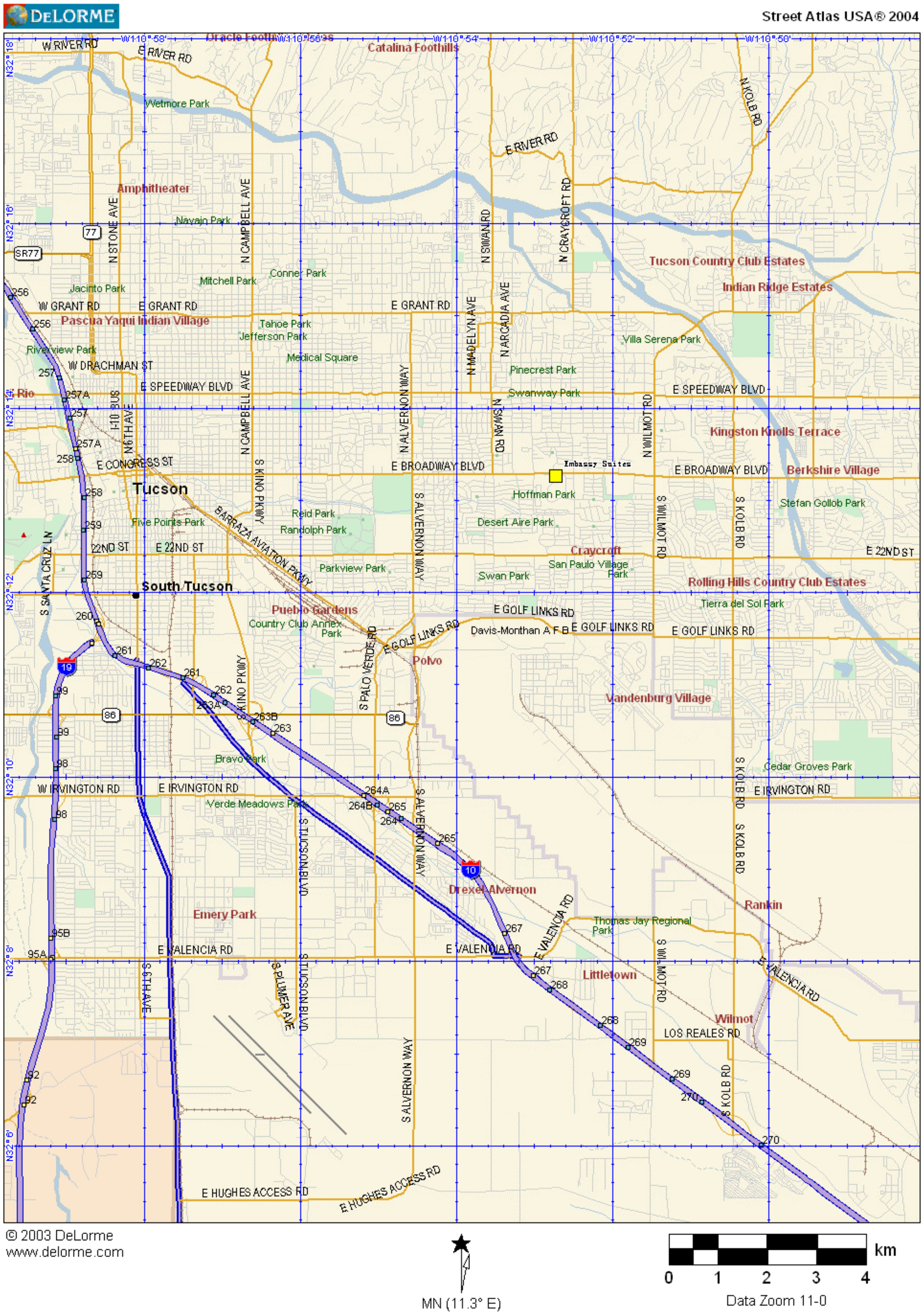

Figure 69. Tucson, AZ Map

Figure 70. Map showing the Broadway area of Tucson, AZ.

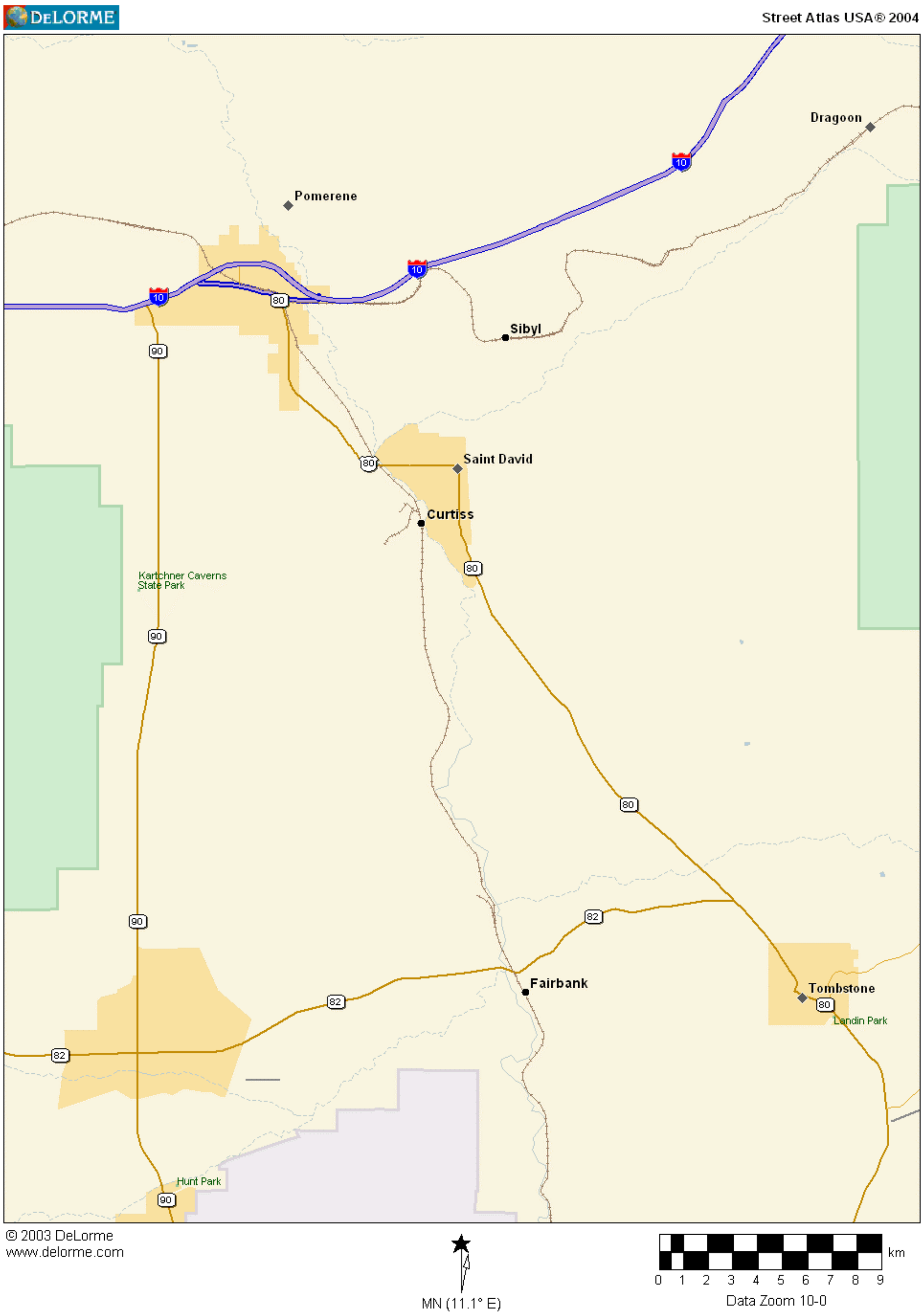

Figure 71. Map showing area north of Tombstone from I-10.

Figure 72. Tombstone, AZ map.

The base of field operations in Tombstone is the ARS Walnut Gulch Field Office. The location is indicated in Figure 72 and the facility is shown in Figure 73.

John Smith Field Supervisor
Walnut Gulch Experimental Watershed
PO Box 213932
Old Bisbee Highway
Tombstone, Arizona 85638
Phone: 520-457-3321
jsmith@tucson.ars.ag.gov

During SMEX04 the point of contact with the ARS SWWRC will be

Tim Keefer
Southwest Watershed Research Center
2000 East Allen Road
Tucson, AZ 85719
Phone: 520-670-6380
tkeefer@tucson.ars.ag.gov

When shipping to Tombstone, ship to the following address:
John Smith
Walnut Gulch Experimental Watershed
PO Box 213
345 Old Bisbee Highway
Tombstone, Arizona 85638
Phone: 520-457-3321

Note that you should inform John Smith (jsmith@tuscon.ars.ag.gov) of incoming packages and label them as SMEX.

When shipping to Tucson, ship to the following address:
Tim Keefer
Southwest Watershed Research Center
2000 East Allen Road
Tucson, AZ 85719
Phone: 520-670-6380

Figure 73. The ARS Tombstone field office.

12.3 SO Region Information

Teams in the SO region will base out of rental houses in several towns, possibly Opodepe and Banamichi. The US teams are expected to base out of Hermosillo at the following hotel

Holiday Inn
Hermosillo
Blvd. Eusebio Kino Y Ramon Corral
Hermosillo, 83010
Mexico
Toll-Free: 018006233300 only in Mexico
Tel: 52-662-2891700
Fax: 52-662-2146473
Email: reservaciones@vallegrande.com.mx

The point of contacts for the SO region are

Chris Watts and Julio Cesar Rodriguez
Departmento de Fisica
Universidad de Sonora
Blvd. Encinas y Rosales
Hermosillo
Sonora 83000 MEXICO
Tel: 011 52 662 259 2108
Fax: 011 52 662 259 2109
email: watts@fisica.uson.mx

The general region and roadmap for the SO region is shown in Figure 74.

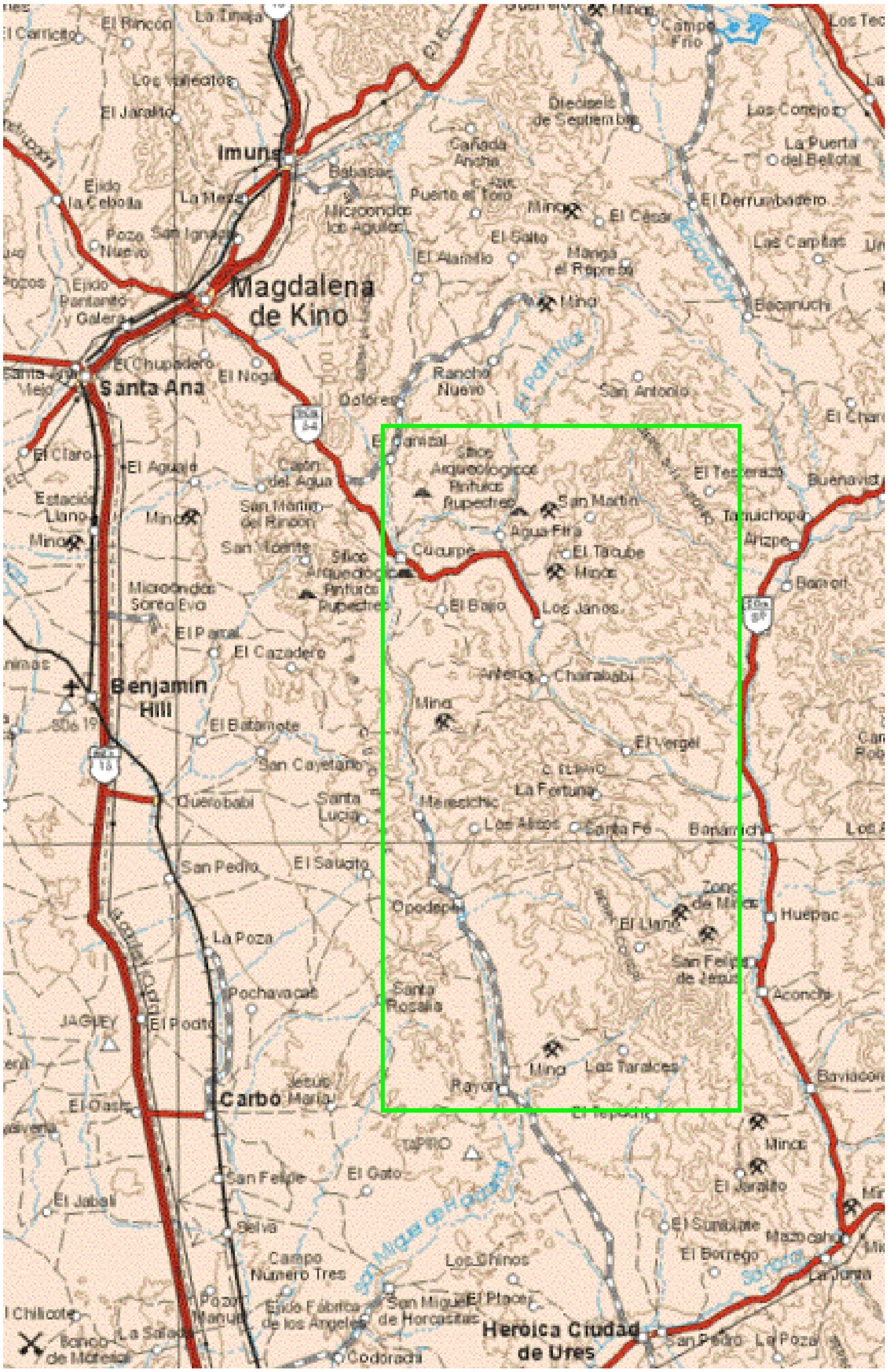

Figure 74. Map of the SO region.

13 SAFETY

13.1 General Field Safety

- Work in teams of two
- Carry a phone
- Know where you are, carry a map
- Dress appropriately, long pants, long sleeves, boots, hat, sunglasses
- Use Sunscreen
- Carry plenty of water; exposure/heat stroke is a serious problem when traveling through the desert.
- Notify your teammate and supervisors of any preexisting conditions or allergies before going into the field.

13.2 Travel

Driving
- Observe speed limits
- Watch for loose gravel, sand, and cattle
- Road intersections are often unsigned.
- Do not leave car unlocked (theft)
- Do not leave all windows sealed when car is unattended (heat buildup)

Flooding
- Flash flooding is a common occurrence, even when it hasn’t rained in your area.
- Use caution when crossing washes and dry river beds.
- Check all washes for soil strength before crossing. Beneath dry surface, a wash could be wet and muddy.
- Roads become extremely slippery after a rain, exercise caution.

Lightning
- This can be a deadly force in the desert, watch the skies for sudden cloud development.
- Do not leave your vehicle in a thunderstorm.

Heat Stroke
- Carry plenty of water for hydration.
- Heat stroke/exposure is a serious problem when traveling through the desert.
- Use sunscreen to protect your skin, SPF30 or above.
- Sunglasses will also help to protect your eyes in the bright desert.

Border Patrol
- The U.S. Border Patrol may have traffic stops setup in the region.
- If you are not a U.S. Citizen, carry your passport.
- Be polite and courteous, always
- Explain experiment and refer them to website for details.

- Do not pick up hitchhikers.

13.3 Flora

Cactus

- Cacti are common in Arizona use caution when walking in fields.
- Wear protective footwear and gloves

Creosote

- Never eat wild flora in AZ, plants such as Creosote have natural toxics which inhibit animals from snacking.
- Many animals make homes beneath Creosote bushes, use caution when sampling or walking near a stand of bushes.

Mesquite

- Mesquite is a common thorny bush in the study region. Take care when walking or sampling near this tree.
- Many animals make homes beneath Mesquite bushes, use caution when sampling or walking near a stand of bushes.

13.4 Fauna

Scorpions

Scorpions sting with their tail, which carries a mild toxin. Call Arizona Poison Control (1-800-362-0101). Ice (do not submerge in water) wound and go to Hospital. Scorpions live under rocks, so just be careful when sampling.

Lizards

Iguana and Gila Monster bites: immediately clean the wound with soap and water. Even the smallest of bite wounds will bleed profusely. Depending on the severity of the wound, you may need to seek professional medical assistance.

Snakes

Two venomous snakes occur in AZ, the rattlesnake and the coral snake. If bitten seek medical help immediately.

Spiders

Both the Brown Recluse and Black Widow spiders nest in the study region. If bitten wash the wound with soap and water. Consult a physician.

Bees, Wasps, Ants

Some people experience severe reactions (Anaphylactic Shock) to bug, ant, wasp, or bee bite/stings. If shock is suspected, call Arizona Poison Control (1-800-362-0101) and administer antihistamines (contained in patent cold medications)

In Case of Emergency Call:
For medical Emergencies call 911

Lynn McKee, SMEX Safety Officer
202-679-3654

Mike Cosh: Asst. Safety Officer
301-221-9984

Rajat Bindlish: Asst. Safety Officer
301-529-4708

13.5 Hospitals

Sierra Vista Regional Medical Center
300 El Camino Real
Sierra Vista, AZ 85635-2812
(520) 458-4641

Figure 75. A map of Sierra Vista with the Sierra Vista Regional Medical Center noted.

Copper Queen Community Hospital
101 Cole Ave
Bisbee, AZ 85603-1327
(520) 432-5383

Figure 76. Map of Bisbee with Copper Queen Community Hospital noted.

Benson Hospital/Helen LeClaire
450 S Ocotillo Ave
Benson, AZ 85602-6403
(520) 586-2261

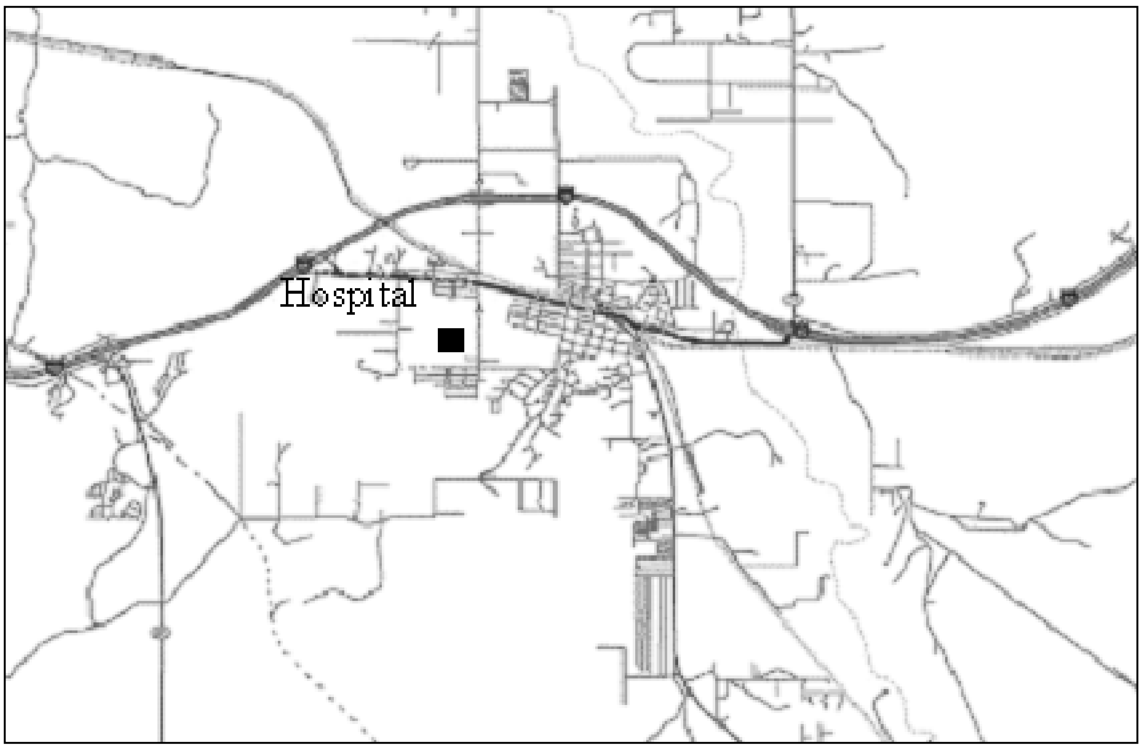

Figure 77. Map of Benson with Benson Hospital noted.